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PROCEEDINGS

SEVENTH MEETING, FIRST HALF, 64TH SESSION

In the Chair:
THE PRESIDENT, COLONEL THE MASTER OF SEMPILL

The Seventh Meeting of the first half of the 64th Session was held in the Lecture Hall of the Royal Society of Arts, 18, John Street, Adelphi, W.C.2, on Thursday, December 6th, 1928.

The PRESIDENT: Squadron Leader Hinkler needed no introduction to the audience. At short notice he had agreed to describe some of his experiences on his wonderful flight to Australia—probably the most interesting flight ever carried out.

MY FLIGHT TO AUSTRALIA

BY

SQUADRON-LEADER J. H. L. B. HINKLER,

A.F.C., D.S.M., R.A.A.F.

My ambition of returning home to Australia by air goes back many years. During the latter part of 1918, as things were beginning to settle down, the possibilities of becoming the owner of an aeroplane and using it to go home, loomed up on my horizon.

Before the Aircraft Disposal came into existence I nearly obtained a Sopwith Camel for this purpose, the type we were using on the Italian Front at the time. On returning to England, after a conference at Sopwiths, I was shown the "Dove" and arrangements were entered into which made the Camel obsolete. Various things intervened and I did not get very far on that mount. Then in the autumn of 1919 came the Avro "Baby." No doubt this machine, in spite of minor difficulties, could have eventually reached the promised land, but at any rate before we were run out, the machine, as you all know, made a flight to Turin.

In my own case, the point at issue was the return to Australia by air. The stern finger of economy pointed out the small machine as the only possible solution to my difficulty. However unsuited the light aeroplane may be for long journeys, yet it had many advantages. Freedom, in the full sense of the word, proceeding (with due respect to the conditions governing flight) fast or otherwise, and along a course just as fancy dictates, at no greater cost than the more usual forms of travelling

I now proceed with the preparations for my undertaking. My "Avian" is the first of its type, and was built for the *Daily Mail* competitions of 1926. Since its first appearance on that occasion it has received a few minor modifica-

tions; some, the result of experience demanding alterations, and others more on account of convenience and suitability of the moment.

One of the first changes, as soon as the machine became my possession, was in the installation of the " Cirrus " motor. Of the mark 2 type and number 5 of the series, it was quite standard in every respect. I would like to stress the fact that it received no doctoring of any kind whatever. I hasten to add that the removal of the " Genet," as originally installed for the competitions, was on account of this engine being Air Ministry property.

At some later date, as an experiment, the original wings of " 64 " section were changed for another set of R.A.F. 28 section. This gave a slight improvement, tending towards a higher cruising speed as well as, of course, a greater top speed. In the region of the lower speeds the honours were with the old wings, but owing to the almost fixed C.P. the machine was now very pleasant, even in rough weather.

During 1927 the machine was flown with varying success at most of the meetings of the season, and at one particular meeting, at Bournemouth, I seem to remember going round quite a number of laps in really close company with the President of this Society.

The opportunity for another try-out came when I had occasion to visit Riga. On our way over, the journey of about 1,200 miles was covered in 10½ hours non-stop. The return trip was made via Berlin in two flights, each of more than 600 miles duration.

Having tried out various schemes and fittings for the purpose of covering long journeys without outside assistance, I will explain how the machine stood at this stage. Petrol systems should of course be beyond question. For long distance requirements, after the provision of the extra tankage, the system should be simple and clear, so that at any moment the pilot knows definitely just how much fuel has been used and exactly what amount remains. In spite of the many fuel gauges available, I have not found any really satisfactory. The scheme I adopted was, first of all, to divide the top centre section tank into two equal capacities of (for this machine) ten gallons each. A kind of junction box with two cocks received one lead from each tank and another pipe-line connected with the carburettor on the engine. By a simple manipulation of these two cocks, either of the ten-gallon divisions of the top centre section tank could be opened to feed the engine. At the same time the other division could be put into communication with a double-acting pump I had made for the job. This enabled me to pump from the main storage tank in the fuselage a further ten gallons into the empty half of the top tank, while the engine continued on the other supply. With over-size " Petroflex " tubing the system was delightfully simple, the engine being at all times gravity fed. Each time a tank ran dry the engine would temporarily " konk," and noting another ten gallons consumed, a turn of the cocks and off she would go on the other waiting supply. Meanwhile, I would get on with a little more pumping. On the average this would happen about every two and a half hours, giving a consumption approximately four gallons per hour while cruising at a speed of eighty-five to ninety miles.

Referring to my patent petrol pump, this was most accommodating. The delivery and feed-pipe lines could be connected up at either end in order to get the best lead. Construction was extremely simple, consisting of three tubes held between two end plates. The middle tube was of larger bore and formed the barrel of the pump. The end plates each housed a suction and delivery valve. Being double acting the flow was continuous and pumping very easily during flight, ten gallons were put through in about five minutes. With this pump I had also arranged for the convenience of taking petrol supplies aboard the machine in much the same way as one sees steam lorries on our roads getting a refill at a roadside water-hole. In some out of the way places petrol is supplied

in large drums too heavy to lift and manipulate over the filler cap, so in my case all I had to do was to roll the drums close to the fuselage, and after inserting a small length of suction pipe, pump the fuel aboard. This piece of tubing was fitted with fine gauze which ensured that all petrol drawn into the tanks had been adequately filtered.

The most important modification to the machine, particularly for single-handed operation, was the fitting of the improved undercarriage of my own design. With other types of aeroplanes not so fitted, when the wings are folded, the extra weight thrown on the tail, together with the awkwardness of tackling the job from in the vicinity of the rudder, means a serious difficulty in moving the machine about on the ground. It also requires a number of persons for man-handling under these conditions. Briefly, my undercarriage ruled out these troubles and I was able to pick up the tail quite easily and wheel the machine about without any outside assistance. Another special advantage is the lowering of the machine's nose when the wings are folded, thus the engine is brought to a favourable position for inspection and routine adjustments. This proved a great asset and facilitated my attention to the engine, especially when this had to be carried out at nights during the flight to Australia. The wide track provided by this design is also an important feature. The lateral stability on the ground is so evident that at times when landing in strong winds there was not the slightest danger of being blown on to a wing-tip. On other occasions when the length of landing run was rather limited, it was possible, as soon as the machine had touched the ground, to put on full rudder and swing round in a sharp circle. There are also a number of other good features, as well as the extreme simplicity of the undercarriage itself.

Just behind the cockpit was fitted a streamline housing to hold a light pneumatic air-raft. During a dress rehearsal I found that the boat could be got ready for use within three minutes, this was under pleasant and easy conditions. Since then I have had time to think it over and am not quite so sure if the results could be duplicated so satisfactorily with plenty of ocean all round. However, the boat, while fortunately not being called upon to play the part for which it was designed, made a very comfortable bed on one or two occasions when I had to spend a night out in the wilds.

There were no extra or special instruments added to the normal set already on the machine. As an aid to navigation I carried a course and speed calculator of my own design which facilitated these problems.

All my maps were taken from the *Times* Atlas. Just before this excellent production became too scarce, a very thorough search of London bore fruit. The scale of those used was mostly 1 : 2,000,000 and 1 : 4,000,000, that is, just a little more than thirty miles and sixty miles to the inch respectively. In spite of the small scale, these contour maps proved very satisfactory, and even as it was, the quantity of maps, etc., for the flight to Australia assumed considerable proportions.

With reference to the " Cirrus " motor, which, as I have already stated, was quite standard, of course I had to put on the finishing touches. One of these touches, quite a gentle touch in fact, was my pet strangler. Being a balanced carburettor, which is fitted to the motor, it follows that the strangler had also to be balanced. This accessory enabled engine starting under any condition to be made ridiculously simple. Not at any time during the entire trip was ever a call made for outside assistance to start up the motor, or was there ever resource to such unfair means as doping or using rags soaked with petrol. The method of starting became much simpler than before, and is as follows: With the petrol turned on and the throttle set, I put the ignition on contact. Pulling the engine over quite leisurely by hand, with the strangler closed, it would fire

on about the third or fourth pull-over and at which the slide is opened and the motor continues to tick over.

On account of the engine running periods being somewhat lengthened, the oil capacity was augmented by four gallons, and carried in a tank connected by a pipe-line to the engine sump. The oil in circulation was at all times contained in the sump and as this was consumed it was replenished from this extra tank. To keep a check on the amount of oil within the engine, an oil level indicator was another addition.

The advantages of a metal airscrew under all the varying conditions on such a flight seem too obvious to repeat. From the snow and coldness of winter at the start, through sandstorms and heavy rains to the heat of a tropical summer at the other end, it imposes a severe test of this very necessary adjunct. At times with a shade temperature of over 120 degrees Fahrenheit, it became so hot that I could not bear to touch it with the unprotected hand for starting purposes. Another minor point is that I was able to dispense with the usual necessity of carrying " prop " covers.

I took with me only four spare K.L.G. sparking plugs, and these were carried in a small tin box containing petrol to aid cleaning. At night while on the engine I would replace the plugs on one side by fresh ones. This was done alternately so that each set did at least two days in the engine between changes. Their condition after this period was so good that it was a sore temptation to forget about them.

To facilitate tappet adjustment a small vise was carried on one of the engine bearers. This fitment proved extremely useful, particularly at some out of the way places, where the attention to the machine was given under rather inconvenient conditions. In these cases all facilities for adjustment and repair had to be carried on the machine. My vise was also provided with an hexagon aperture, in which the central electrode of the sparking plug could be inserted and held fast while dismantling or re-assembling.

And now we arrive at the period of my departure, with the machine already having covered approximately fifteen thousand miles.

The start was made just before dawn at 6.45 on the morning of February 7th, 1928. Loaded up to the full capacity of fuel, that is with 46 gallons in the main storage tank in the fuselage and the 20 gallons up in the centre section, the machine took off exceptionally well considering the soggy nature of Croydon Aerodrome at that period. Under a heavy overcast sky with only moderate visibility, the coast of England was crossed between Hastings and Dungeness within half-an-hour. After this a complete cover of low-lying cloud hid the whole countryside, and my next check was Lyons at 11.46 a.m. I intended to cross the Alps, but found the head wind so strong at height that my ground speed was reduced to the neighbourhood of 30 miles per hour. Therefore I flew very low, down the Rhone Valley, and even so could only make good a little over 50 miles per hour as far as San Raphael, where I crossed over the Mediterranean coast. Although I was aiming for Rome, I began to feel the necessity of choosing some nearer objective as it was now past two o'clock in the afternoon (English time) and only two more hours of daylight. Instead of flying direct via Corsica, I decided to follow the coast round and make a landing at one of the Italian coastal aerodromes before nightfall. However, darkness fell when I was out at sea, crossing the Gulf of Genoa, off Leghorn, and left me no choice but to carry on for Rome. I had previously landed there in 1920 with the Avro " Baby." Also, knowing the modern facilities for night flying that are in operation at London, Paris and Berlin, I compared Rome, a capital city as having similar conveniences and felt much heartened thereby. It all seemed so simple, just fly round a few times and then the welcoming lights would be turned on, which would guide me to a nice landing after this long day's journey. But in

the meantime still another 200 miles of darkness separated me from Rome, and my machine had not been fitted up for night flying. Fortunately, I carried a small pocket electric torch which I used occasionally to read my instruments. The waning moon rose about eight o'clock (local time), but until that hour the darkness was complete, so much so, that I could not even discern the coastline below me. The lights of the few towns on the route helped me tremendously. When I arrived over Rome I flew round to the south-east in the direction where the aerodrome was situated during my previous visit, but over a half-hour elapsed before it was located. With my pocket torch I flashed a kind of S.O.S. which did not bring forth the required results. To further suggest my wants I swooped low a number of times, as though trying to land, but still no response. Therefore I had to make an attempt at a landing in the dark. With the moon at my back this came off all right, although it was without regard to a cross wind. The drift was very satisfactorily countered by my wide track undercarriage, which took a severe bump without ill-effects of any kind. After taxying up to the sheds I was met by a large crowd of Italian soldiers who became violently interested in our night arrival. It was now just on nine o'clock and the duration of flight, including my wanderings in search of the aerodrome, was twelve and three-quarter hours.

By the time I got clear of the many formalities one encounters on arriving in a foreign country it was too late to have a look round the machine. With the aid of a member of the aerodrome staff I went into the city, changed some money and had my first meal for the day. The clock had by this time wandered round to the hour of one a.m., and feeling a little tired a few hours of rest were sought as a reward for the progress of the opening day's run.

Four hours later, back at the aerodrome I was busy going round the machine preparing for another day. As soon as daylight appeared I was most anxious to look round and survey the aerodrome surroundings. It was with feelings of great discomfort that I saw for the first time a forest of high wireless masts; as in circling round to land in the darkness I must have missed them by inches only. Except for a little job on the cowling I was pleased to find everything in order, but attending to the machine in the morning prevented another early start. However, nine o'clock saw us ready for the air and about to leave under perfect flying conditions. This must be the rush hour at Centocelle, as I had to line up in a queue with some five other machines, each receiving the all clear signal to take-off in turn. The run down the coast of Italy was very pleasant, most of the country is very rugged and drops into the sea almost vertical, with few sandy beaches where a landing would be possible. My objective for the day was Malta and this stage of practically all coastline flying was covered in six hours. Being met by the R.A.F. on landing, I was offered every assistance and had the machine serviced before nightfall.

That night the wind began to blow and the rain came down and for a time it appeared that the weather conditions were going to hold me up. Nevertheless, up and out early next morning, hoping for the best, I took-off at 7 a.m. under a heavy overcast sky. The stage ahead was 450 miles of open sea, crossing direct to Benghazi. The heavy rain had made the aerodrome soft and sticky, but we got off without any trouble and almost as quickly as it takes to tell the coastline had faded from my sight. Sitting tight on a calculated course with the clock slowly ticking off the hours we passed through many varying weather conditions. During the first couple of hundred miles conditions were improving until at about 10 o'clock the blue sky and good visibility gave great hopes, although down below there was quite a sea running. The pleasant flying conditions did not last long, as when about five hours out heavy storm clouds loomed up ahead, blocking my route entirely. For some time afterwards I was making detour after detour trying to find the best passage through the numerous storms. It was also

necessary to keep a strict check on these variations from the calculated course, and later on it was with great pleasure that land was sighted. As I got nearer I could make out the form of a town which eventually turned out to be Benghazi. A landing was made on the Italian aerodrome at the back of the town to signal Malta " all clear." Without any further delay we were in the air again, hoping to reach Tebruk before nightfall. The strong easterly wind which had affected me during the sea crossing now knocked my speed still lower. This handicap was increased by the fact that in flying east the amount of daylight is somewhat shortened than to one remaining at the same place. The combined effect of the head wind and the setting sun left me still flying out over the desert, approximately 40 miles from Tebruk. Being a complete stranger to these parts I dared not chance the risks of arriving after nightfall, so with no other choice I had to make a landing out in the wilds.

Although the country appeared good from the air, at close quarters it showed to have numerous tufts on the surface, and while landing in the dusk these tufts bumped the machine about rather badly. Looking over my wheel tracks afterwards I realised what a lot I owed to my sturdy little undercarriage. These tufts consist of camelthorn with the sand heaped up and hardened round the roots and are about a foot in height. Complete darkness came soon after the landing and with the world all to myself I took out the pneumatic boat and pumped it up. Turned upside down it provided a comfortable bed and under the wing I enjoyed luxuries never before experienced in these parts.

Long before dawn I was up and preparing for the coming day. My early rising had not yet become a habit; included in my equipment, besides the proverbial tooth brush, I carried a small alarm clock which performed with almost terrifying regularity. Having stowed my boat-bed, as soon as there was sufficient light, one of my first jobs was to clear some kind of runway. The best that could be done with the bare hands gave a run of about 60 yards and the machine required to be guided carefully as there were patches to be passed over by straddling the wheels on either side. I lessened my petrol load to the minimum, and although the sun had begun to warm things up by now, in spite of the unfavourable conditions the actual take-off was a revelation. With a full five yards to spare the machine seemed to be suddenly lifted clear of the ground and we were safely on the way to Tebruk. It was just as well I landed at this point because later, on the way to Tebruk, the country becomes much worse and even by daylight it would not have been possible to make a safe landing. At the aerodrome the Italian squadron there was preparing to come out and search. Owing to the hostile nature of the tribes it is most desirable to notify the authorities of one's movements. Tebruk has a large aerodrome adjacent to the town with tall wireless masts in the vicinity, but the surface is hard and gravelly. After refuelling and explaining my night out, over a cup of coffee, we took the air again accompanied by three Savoias as an escort for the first few miles, aiming this time for Ramleh in Palestine. Egypt was, so to speak, out of bounds for me, as I was unable to give the required fifteen days' notice.

The activities of the morning occupying valuable daylight was the cause of a delay which upset my calculations and for the second time I got caught by the oncoming darkness for another night out in the desert. Picking out the best looking area the landing was a close thing. As I touched, the wheels sunk in the soft sand, almost causing the machine to nose over. Although we were down all right it was an impossibility to get off from such a surface, in fact it was a serious problem how and where to move the machine. Growing fears of a protracted delay provided extra energy to find a way out. After considerable searching I came across an area which from the air had looked a waste and rough piece of ground. A close examination showed that although uneven, the sandy patches were hard in places, so that by careful manœuvring a run of some

seventy-five yards was just possible. My experience that very same morning gave every encouragement, and if I could only keep within the strip containing the firmer sand all would be well. The strip was about as straight as a country lane, but again the choice was very forced. The problem of moving the machine solved itself with the sudden appearance of numerous Arabs. In the morning the machine again responded to the call for that extra little bit and soon after we arrived at Ramleh. Arriving just in time for breakfast, the R.A.F. very kindly saw to it that the first time I sat down to a meal since leaving Malta more than made up for the omissions on the way. My intentions were to quickly refuel the machine and get across to Baghdad, but it was a Saturday morning and the troops were on parade, so that by the time I was able to make my wants known the day had so far advanced that I could not risk another night in the desert. I might here mention that since leaving Malta some two thousand miles back the engine and machine had not been touched or even inspected. Seeing nothing else for it but to remain at Ramleh for the remainder of the day, it was a good opportunity for a special look round. With great satisfaction I could not find what I looked for, that is, there was nothing out of order or requiring adjustments. I was interrupted in the course of my work at various intervals having to attend to a number of international travelling formalities. A demand to parade before the local M.O. was the first interruption, then soon after along came the Customs people. I would like to point out how much I was helped through these difficulties by the R.A.F.

The first thing next morning we took off with a full load, and heading straight for the hills, climbed just fast enough to keep clear. A direct course was set for the Euphrates, and while over the desert the first and only check obtained was one of the desert landing grounds, marked " M " on the air route between Gaza and Baghdad. Basra, 950 miles distant from Ramleh, was reached after 9½ hours' flying. While out over the dreary waste the even note of the engine makes pleasant music of an otherwise drab monotonous exhaust, but the desert is always just the same barren sandy plains reaching to the horizon in every direction. At Shaibah, the aerodrome for Basra, I was kept busy until nearly midnight, and the machine stood ready for another day.

And so my story continues. With the machine serviced, what was left of the remaining hours of darkness provided cover for Nature's wonderful reviver, sleep, even if only for a couple of hours to launch us forth and keep us up for still another day. Before the dawn had properly arrived, the Cirrus ticking over as confidently as ever, would respond perfectly to the movement of the throttle lever and away we would go, racing to meet the rising sun of a new day. Each day, all day long, sitting with the nose of the machine ever pointing in the direction of Australia; looking down on desert, coast, sea, jungle and mountains, while passing through sunshine, sandstorms, tropical downpours, clear skies and periods of heat haze that reduced visibility to less than one mile and coming down late in the afternoon after scoring some further hundreds of miles towards my goal.

On the fifteenth day out, after a trying time with tropical storms all the way along the islands of the Dutch East Indies, we pulled up at the emergency landing ground at Bima Bay. The town of Bima is some fifteen miles to the north. There is no accommodation at the aerodrome, but the Dutch Commissioner kindly fixed me up with a portable bed under the verandah of one of the native huts close by. I wanted to be off very early in the morning, so it was necessary to be right on the spot. Ahead of me was water practically the whole of the way of nearly 1,000 miles to Australia. The risks of getting caught out by darkness had to be ruled right out. It is much easier to leave a place you know in the dark than to arrive at one you don't know. So just before the light of the sixteenth dawn we had ascended, the high mountains on the south

to be crossed to avoid a wide detour, demanding the very best of my machine. After leaving the Bima ground there is no chance of making any kind of forced landing, the southern coast of the island is mountainous and rocky in the extreme. About ten o'clock Kupang, on the island of Timor, came into sight through a hole in the clouds, then again more water. The notes in my diary refer mainly to petrol tanks going dry and changing over. Such entries as "Change tanks 8.20," "Kupang 10.15," "Change tanks 10.53," "Change tanks 1.26," etc., and so on until at last the horizon seems to show a kink in it. Can I be sure this time? For the last two hours the distant clouds have been tricking me into thinking land was visible. But this time the appearance of land on the sky-line agrees with my calculations that Bathurst Island should be coming into the picture. The visibility was medium, but sure enough that was my first sight of Australia, and within fifteen minutes I was abreast of the point which now lay away on my left. So near and yet so far below, the ocean bed could be seen quite clearly and the submarine growth most interesting. Within an hour I was circling round to land at the aerodrome at Port Darwin. The populace, more optimistic than myself of arriving to schedule, had turned out in full strength to welcome me. I was a little tired, but certainly happy.

Timetable

Date.	Day.	Route.	Fly Time.	Distance Traversed.
Feb. 7.	1.	London-Rome. ...	12 hrs. 45 m.	1100 miles.
,, 8.	2.	Rome-Malta. ...	5 hrs. 53 m.	540 ,,
,, 9.	3.	Malta-N. Africa. ...	9 hrs. 6 m.	725 ,,
,, 10.	4.	N. Africa-Egyptian Bdr.	8 hrs. 15 m.	670 ,,
,, 11.	5.	On to Ramleh. ...	1 hr. 10 m.	70 ,,
,, 12.	6.	Ramleh-Basra. ...	9 hrs. 30 m.	950 ,,
,, 13.	7.	Basra-Jask. ...	8 hrs. 35 m.	792 ,,
,, 14.	8.	Jask-Karachi. ...	7 hrs. 3 m.	600 ,,
,, 15.	9.	Karachi-Cawnpore. ...	9 hrs. 35 m.	812 ,,
,, 16.	10.	Cawnpore-Calcutta. ...	6 hrs. 0 m.	677 ,,
,, 17.	11.	Calcutta-Rangoon. ...	7 hrs. 55 m.	670 ,,
,, 18.	12.	Rangoon-Victoria Pt. ...	7 hrs. 30 m.	560 ,,
,, 19.	13.	Victoria Pt.-Singapore ...	9 hrs. 0 m.	790 ,,
,, 20.	14.	Singapore-Kalidjati. ...	7 hrs. 34 m.	620 ,,
,, 21.	15.	Kalidjati-Bima. ...	8 hrs. 47 m.	924 ,,
,, 22.	16.	Bima-Darwin. ...	10 hrs. 30 m.	950 ,,
			129 hrs. 8 m.	11450 miles.

Vote of Thanks

Dr. A. P. Thurston: In proposing a vote of thanks to Squadron Leader Hinkler for his lecture, Dr. Thurston said he was very glad indeed of the opportunity to congratulate a splendid sportsman upon a magnificent achievement. Squadron Leader Hinkler had forged another link with the Empire.

Colonel Barrett Lennard: He would like to second the vote of thanks. Most justly Squadron Leader Hinkler had been praised for his courage and for the great fortitude he had shown in meeting the very serious fatigues which he must have had to meet during the very wonderful flight he had made. Scarcely less admirable was his modesty, carried almost to the extreme. One feature of his flight which was of very great practical importance, but of which very little had been heard, was that, brave man though he was, there was no man less reckless than he. He had had certain materials at hand with which to make

this flight, and one of the great lessons he had taught was that one could not do anything even with the best material if one did not look after it. He had stated from time to time during his lecture that he had looked at his machine and engine, but on other occasions he had said that he had never neglected an opportunity of ensuring that his engine and machine were in perfect condition, and when he had taken off on that dreadfully long last stage, after days and days of such anxieties as must have beset him, he had been quite confident that if any man could fly any machine with any engine in it across so great a stretch, he was going to do it. He had left nothing to chance that he himself could control. Many persons were flying aeroplanes nowadays, and one was not surprised to know that very few of them indeed had that skill and knowledge of the maintenance of machine and engine which Squadron Leader Hinkler had, but it could not be too often impressed upon learners that the best material in the world would not save them from disaster, and would not give them the service it was capable of giving, unless they knew how to look after their machine and engine, and, knowing it, did look after them. Squadron Leader Hinkler's flight had taught us that very practical lesson, that one must leave nothing to chance, as he had left nothing to chance.

Mr. GRIFFITH BREWER: He would also like to express his congratulations. Squadron Leader Hinkler was celebrated here not only as a flier, but also by reason of the fact that he had been able to improve his machine and so advance the development of aviation. That was very much to his credit. Men such as he, who, in learning how to fly skilfully and to look after their machines, could improve those machines, were of great value to the constructors. Fliers alone would not develop aviation to any great extent, nor would the constructors alone; it was the men who could combine the two great skills and thus produce improvements in detail and find out the weak parts of machines whose work was of the greatest value to the advance of aviation.

THE PRESIDENT: When speaking privately to Squadron Leader Hinkler he had expressed the hope that he would be able to tell the story of his wonderful flight to very much bigger audiences, and it was still to be hoped that he would, because it was of absorbing interest to everybody. He had flown the way out to Australia alone, and one could only hope that in a very short time we should be flying along a commercial route all the way to Australia. It would be very different flying from that experienced by Squadron Leader Hinkler, however, for multi-engined machines would be used, and there would be plenty of stopping places on the way. There were very few people who would have the endurance and courage necessary for the accomplishment of such a flight as Squadron Leader Hinkler had achieved, and the Society was very grateful to him for having lectured upon it at such short notice.

The meeting then closed.

PROCEEDINGS

SEVENTH MEETING, SECOND HALF, 64TH SESSION

In the Chair:

THE PRESIDENT, COLONEL THE MASTER OF SEMPILL

HANDLING AND MOORING OF AIRSHIPS

BY

MAJOR G. H. SCOTT, C.B.E., A.F.C., F.R.AE.S.

The seventh meeting of the second half of the 64th Session was held in the Lecture Hall of the Royal Society of Arts, 18, John Street, Adelphi, W.C.2, on April 4th, 1929.

The PRESIDENT: Major Scott was very well known to almost everybody, perhaps mainly on account of the wonderful flight which was accomplished under his command in the airship R.34, across the Atlantic to New York and back again a few years ago. He had many other claims to fame, however, in connection with the development of airships. At present he is in charge, at Cardington, of the training of the crews of the R.100 and R.101, which airships were approaching completion, and he would captain those two ships.

Major G. H. SCOTT: A good deal has been written, both in this country and abroad, on the problems associated with the handling and mooring of airships. Many of these papers or articles are of little value owing to the author failing to appreciate the essential requirements and limitations of the problem. It would therefore not be out of place to consider what are the essential requirements and what limitations exist.

The peculiar drawbacks associated with the landing of aeroplanes, namely the high horizontal speed required to maintain the dynamic lift, and the long unobstructed run on the ground, need not be considered when dealing with the landing manœuvres of airships.

On the other hand, the large dimensions as compared to its mass, and the big surfaces exposed to wind pressures, introduce limitations in the handling of an airship as compared with the smaller and more heavily built aeroplane.

Although the hull of an airship is strong enough to withstand the wind pressure, any restriction to free motion must be exerted at individual points on the hull, and the principal problem the designer has to face, when considering handling arrangements, is the distribution of the local load exerted at these points, either by the Mooring Tower, the guy ropes, or other devices, through the members of the structure in order to counter the wind pressure exerted over the large surface of the hull or fins, and the limiting factor is largely controlled by the amount of local load that can be satisfactorily dealt with.

Therefore, in considering any system of handling, it is essential to consider the local loads to which the airships will be subjected, and the ability of the airship to withstand those loads.

Probably the easiest point at which to obtain real strength in the structure of an airship is the extreme nose, and this is one of the reasons why Tower Mooring, in which the airship is attached to the Tower by the nose, would

appear to be the logical method of mooring. It must not be assumed that the loads at the nose in Tower mooring only affect the actual nose piece itself; the Tower mooring condition actually controls the design of the main framework of the airship for about one third of its length from the bow aft.

But when moored to a Tower and allowed to swing freely in the wind, no other important external local loads are exerted on the airship.

When handling an airship on the ground, or in and out of a shed, it is necessary to manœuvre the airship into a position that may not be in the line of the wind; it is therefore necessary to exert external forces at points other than the nose, and to obtain the necessary local strength at these points is not so simple, and the strength that can be obtained at these points limits the cross component of wind that can be dealt with.

There is the further problem when handling on the ground of restricting vertical motion of the airship, and so prevent collision with the ground.

Another very important factor in any system of mooring or handling is the necessity of preventing snubbing or any sudden tautening of a slack rope, as owing to the mass of the airship, any snubbing, even at low velocities, is bound to bring heavy local stresses on the structure.

In other words, the controlling factor in any system of handling or mooring is the maximum local load that the system could exert on the structure of the airship, and is the essential problem to be considered. Practically all other points are questions of convenience, and subsidiary to this main point.

Keeping this point in mind we may now consider the actual problem of handling the airship when on the ground, more particularly handling in and out of the shed.

Section I.—Handling In and Out of the Shed

The first question to consider in handling an airship into or out of the shed is the type of shed employed in discussing this question. I would like to refer to a very excellent article written by Professor O. Krell and published in one of the German Aeronautical Papers.*

This article deals very fully with the many types of sheds that have been built or proposed, and is freely illustrated. Many of the diagrams show the flow of air round these sheds, and the formation of eddies in the mouth of the shed, which would seriously affect the handling of airships.

There is one very noticeable fact in the article, which is that the whole question has been considered on the assumption that the lee doors of a shed are always used, whereas, in this country, the tendency has been to use the weather door of the shed, or rather where possible, to take an airship into the shed tail first and out bow first.

There are a number of advantages in employing this method of handling, one of the most important being the fact that the large fins on the tail of the airship, more particularly the top fin, are more affected by gusts and eddies than the bow; also owing to the streamlined form of a modern airship the forward handling guys are situated nearer to the bow than the after guys are to the tail. It is therefore easier to control the bow of an airship in a side gust than it is in the stern, and by handling out of a shed bow first and into a shed tail first the fins do not leave the shed until the last moment when coming out, and are in the shelter of the shed at the earliest possible moment when entering.

Another advantage is that when the wind is blowing at an angle to the shed, the airship is allowed to swing about the bow into the wind as soon as clear of the shed, and if she is handled out bow first she will swing away from

* "Technical Considerations on the Landing of Large Airships," by Von O. Krell, from the Zeitschrift für Flugtechnik und Motorluftschiffahrt.

the shed, whereas, if she is handled out stern first, she will swing towards the shed.

This method of handling entails using the weather door.

There is another case in which the airship is lying in the shed, in such a position that her tail is to the wind. In this case she must be taken out of the lee door, so as to swing clear of the shed as soon as the tail leaves the shed, but here again the airship is handled out bow first.

It will thus be seen that the tendency in this country is always to use the weather door for handling into the shed, and to also use the weather door when handling out of the shed, except in the case where the ship is lying with her tail to the wind.

It was for this reason the sheds at Cardington, which have a door at one end only, have this door situated at the south-west end, or the prevailing weather end.

The diagrams with which Professor Krell illustrates his article showing the wind currents round a shed, indicate the superior conditions for handling at the weather end of a shed, and tend to confirm the advantages of the British method.

The principal criticism that is levelled against the use of the weather door is that if the airship breaks away from the landing party she will drift back on to the shed, whereas, if the lee door is used, she will drift clear of the shed. But as no attempt should be made to handle an airship either into or out of a shed when the conditions are such that there is a serious danger of the airship breaking away from the landing party, the balance of advantages would appear to be strongly in favour of the weather door, or rather of always handling an airship out nose first and in tail first.

In spite of the fact that Professor Krell has omitted to consider the question of the use of the weather door, his general criticism of the various types of shed is sound, and well worthy of consideration, and in this section of the paper I admit to making full use of many of his arguments.

The majority of airship sheds so far constructed are of steel with vertical or very nearly vertical sides, and reasonably low pitched roof, and although in many cases in the past sheds capable of housing two ships side by side were constructed, the tendency to-day is to build single-ship sheds. This is largely due to the great increase in size of airships, more particularly to the very greatly increased diameters and the excessively large span that would be required if a double shed was constructed.

In some cases such as at Howden a double shed has been built with a line of supports down the centre of the shed, which virtually produces two single sheds, as far as roof span is concerned.

This type of double shed has certain economical advantages in construction and maintenance, but from the handling point of view is inferior to two independent sheds, owing to the increased eddies caused by the larger door areas.

The question of a ferro concrete shed as opposed to a steel structure is almost entirely an economic one, there being no important difference in operating from them, although it is probable the ferro concrete shed may have a slight advantage, owing to the more constant temperature that would prevail inside, in hot climates, and that it may be possible to heat such a shed in cold climates, whereas this is almost impossible in a steel shed.

Revolving sheds have often been under consideration, and a considerable amount of experience has been obtained from two revolving sheds in Germany, a comparatively small single shed at Biesdorf and a double shed at Nordholz.

There is no doubt that these revolving sheds considerably facilitated the handling of airships, but largely due to their big initial cost no attempt has been made to construct one since the war.

The introduction of the Mooring Tower has removed the necessity of a revolving shed, as an airship can moor and await suitable weather to enter the shed.

A large number of other proposals for housing an airship have been suggested, but even when the suggestion is a practical one, the cost is so great as compared with a Mooring Tower and a fixed shed, that unless the Mooring Tower should prove a failure, there is, I feel, very little likelihood of them being tried out.

A very interesting suggestion is put forward by Professor Krell, in which he proposes to employ a streamline shed, and thus reduce the formation of eddies round the door. But as the whole advantage of the streamline form would be lost if the shed was not in dead alignment with the wind it is essential to have a revolving shed.

The large initial cost is therefore the chief objection to the scheme.

It therefore would appear that for the immediate future we should assume the shed to be a fixed shed of conventional type, either of steel or ferro concrete.

The number and type of doors is the next point to consider.

From the point of view of economy in most parts of the world doors at both ends are not essential, but if a door at one end only is fitted occasions will occur when the lack of a door at the other end will impose limitations, and therefore delays in handling. It is probable, however, in this country where there is a very definite prevailing wind, that, provided the doors are placed at the correct end of the shed, *i.e.*, south-west end, the occasions on which delay will occur owing to lack of doors at the north-east end will be rare.

The type of door is again important; so far no large shed has been erected in this country with other than flat doors, that is, doors that either slide sideways from in front of the shed or open out radially. In both cases, when open, these doors form an additional obstruction to the flow of air over the shed, and tend to create eddies in the mouth of the shed. This objection is not so serious when using the weather door as when using the lee door, but is not one that can be neglected, and from this point of view the folding shutter or blind type of door that was fitted to several of the German sheds has an advantage.

We now come to the process of handling an airship in or out of her shed, and it might be advisable to consider what are the requirements in this direction.

It is my personal opinion that with the large airships of the size of R.100 and R.101 and upwards, it will be practically impossible to handle them on the ground or in and out of the sheds, except in light winds whose direction is up and down the shed, and not at all in winds that have any appreciable component across the shed. In this country handling has always been carried out by man power, no mechanical method having so far been adopted.

The introduction of handling rails, as used in Germany and at Lakehurst, will appreciably reduce the number of landing party required, but will not permit of handling an airship in and out of a shed in increased wind velocities to any appreciable extent.

The handling rail can, however, be accepted as a proved method and will probably be fitted to all operating sheds in the future, as where continuous operations or any considerable amount of handling has to take place, the saving in personnel will justify the expenditure on the rails.

The handling rail consists of a girder fixed to the ground extending along the inside of the shed, and out through the doors, and over the aerodrome to a distance of about $1\frac{1}{4}$ to $1\frac{1}{2}$ times the length of the shed. Trolleys are constructed to run along this rail and so arranged as to be capable of easy longitudinal motion while exerting an upward and side load on the rail. To

these trolleys the side guys of the airship are attached, one either side forward and aft.

When the airship is walked out of, or into the shed, these trolleys are towed by a number of men so as to maintain them in the correct relative position to the ship, *i.e.*, at right angles to the centre line of the airship, and by exerting a pull on the guys from the rail restrict the airship to a motion along a line passing through the centre of the shed.

A party of men is still required to support the cars of handling frames, and prevent the airship coming down on to the ground.

When taking a ship out, as soon as the stern is clear of the shed, the after guys are slipped from their trolleys and the airship allowed to swing head to wind before the forward guys are released.

When housing an airship the forward guys are first attached to the trolleys and the stern then pulled round to the correct position for entering the shed, and the after guys attached.

Two types of rails have been tried, one the slot type in which all the trolley wheels are located inside the rail. This type has the advantage, in that it can be sunk flush with the ground, its chief disadvantage being the difficulty of keeping the slot clear of obstruction, particularly snow or ice, and the difficulty of cleaning the running surfaces.

In the second type the trolley straddles the rail, and all running surfaces are on the outside of the rail. The chief disadvantage lies in the fact that it cannot be completely sunk into the floor of the shed or the ground, and thus causes an obstruction.

There are advocates for both types, but having had no experience, I am not qualified to express an opinion, although I feel the danger to the airship from the jamming of the trolleys which would appear to be more likely in the slot type than in the external type, is a more serious objection than the slight obstruction caused by the second type.

A number of other mechanical methods of handling an airship into a shed have been suggested, and some are at present under consideration.

In the United States a short mobile mooring mast is under construction, and consists of a tripod stub mast with the three legs of the mast resting on caterpillar tractors. The proposed method of operation is to moor the airship to the stub mast and then move the mast complete with airship into the shed, the after guys of the airship being manned by the landing party or attached to the trolleys of the handling rails.

There would appear to be a number of objections to such a scheme, in the first place any unevenness of the aerodrome would be magnified by the height of the mast and cause sudden acceleration or deceleration of the mooring point, any motion of this nature will put heavy stresses in the nose of the airship. The synchronising of three separate tractors is by no means an easy matter.

The first objection could to a certain extent be eliminated by substituting for the tractors, bogeys running on carefully laid down tracks, in which case the method would be very similar to that tried out early in the war at Kingsnorth, using a non-rigid airship. The experiment was a complete failure.

A practical demonstration of the difficulty of synchronising tractors was given when an attempt was made to handle one of the early rigids with five tractors; the difficulty was certainly accentuated in this case by the old type of tractor used and the fact they were not all of the same pattern, and it is possible that with specially designed tractors this method might be satisfactorily developed. It is probable that each tractor would have to carry a winch to which the guy would be attached, so as to be in a position to make the finer adjustments by paying out or hauling in the guy on the winch.

Another suggested method is to build a mooring mast at the end of a revolving shed. After landing to the mast the nose of the airship travels down a vertical guide on to a portable section of the mast in the mouth of the shed. This section is then moved into the shed with the airship attached to it.

Apart from the objection that this system necessitates the use of a revolving shed, the eddies caused by the shed would make landing to such a mast a dangerous operation.

A number of other methods have been suggested at various times, which I do not propose to deal with. In most cases the cost of the proposal would be prohibitive, and in many cases the suggestions are unworkable, and show a complete lack of appreciation of the controlling factors in handling airships in and out of their sheds.

Before discussing mooring and landing to a mooring system, we may consider the question of landing to a landing party. Papers have already been read before this Society dealing with piloting and landing of airships, and as far as landing to a landing party is concerned, I think only one new factor has been introduced in recent years, and that is the effect of increase in size.

The principal effect of increase in size is to reduce at any given velocity the dynamic forces on the airship as compared with her gross lift, and as variations in buoyancies due to variations in air temperature are proportional to the gross lift, either the pilot must accurately forecast these variations or land faster.

An endeavour to more accurately forecast the conditions is being made by fitting electrically recording thermometers in the meteorological hut, giving the temperature at two or more levels, and by improving the organisation for the transmission of the information to the airship before landing, but even then it will probably be necessary to land the two new airships, the R.100 and R.101, faster than the older R.33 class.

This introduces another point, owing to the good aerodynamic form of these ships compared with previous airships and their greatly reduced head resistance as compared with their gross weight. These two airships will maintain their air speed for a considerably greater time and distance than the previous airships. The necessity for ample astern power is therefore increased.

The fact that the necessity for astern power increases with size of airship is borne out by past experience. With the small non-rigid airship of the Blimp and Coastal type, the necessity for astern power was never felt, as these airships could be landed comparatively slowly even in a dead calm and rapidly lost headway when the engine was stopped or slowed down. As size was increased it was found essential to fit astern power, and although rarely used in the 1,000,000 cu. ft. airships of the R.23 class, is almost invariably used in the better streamlined and larger R.33 class.

Another danger that becomes increasingly great as the size of airship increases is the danger of carrying away one or more members of the landing party, if the airship is landed too light, as the amount of surplus buoyancy an airship should have when landing is roughly proportional to the gross lift.

It will thus be seen that as the size of airship increases, it becomes increasingly more difficult to land to a landing party, and more and more essential to land to a mechanically operated system such as a mooring tower.

It is my personal opinion that the airship pilot of the future will look with horror at the idea of landing to a landing party and a manœuvre only to be carried out in cases of extreme emergency.

This leads us to the question of mooring and landing to a mooring or mechanical system.

Three years ago I read the paper before this Society on the "Development of Airship Mooring," and I do not propose to repeat myself, and although

little in the way of airship operation has taken place in this country, several new problems and new proposals have arisen since I read my last paper.

One of the most important is the American proposal of a short or stub mooring mast as opposed to the tall tower hitherto used in this country and the United States.

The proposal briefly consists in mooring an airship close to the ground with the nose of the airship secured to a mast of just sufficient height to keep the cars clear of the ground when on a horizontal keel; the cars are then secured to trolleys or weighted bogeys in such a way that they prevent any vertical motion of the tail of the airship either upwards or downwards.

Several advantages are claimed for this system of mooring, but I think the chief factor which leads to the proposal was a difficulty experienced at Lakehurst in keeping the tail of the airship, when moored to the high mast, from taking up extreme angles under varying temperature conditions. The method which has been used in this country for preventing this vertical motion of the tail is by hanging a number of balance weights from the airship in such a way that they are either picked up off the ground or lowered on to the ground, as the tail of the airship rises or falls. The increase or decrease of the weight slung on the airship thus counterbalancing any sudden variation of buoyancy.

These balance weights take the form either of weighted wheels or garden rollers, so that when on the ground they do not appreciably restrict the free swing of the airship about the mooring tower with variation of wind direction.

In the new airships the proposal is to fit four such balance weights weighing about one ton each.

A number of continuous temperature records have been taken at the Mooring Base in Egypt, and records are being collected at Karachi, also a number of the extreme cases have been reported from Lakehurst, and taking the most severe case yet recorded of a sudden change of air temperature, it is calculated the balance weights as proposed would be adequate to prevent any undue vertical motion. We feel convinced that an airship can be maintained on practically a level hull at a high tower, and without asking for any exceptional skill on the part of the airship crew. There is no need to modify the system in order to overcome the difficulty experienced at Lakehurst.

With regard to the other claims made for the stub mast, a summary of the advantages and disadvantages of the two systems is given below.

High Mast

Advantages.

(*a*) Landing can be made possible with safety in comparatively bad weather.

(*b*) Even in bad weather a party of 14 to 20 men is all that is required.

(*c*) The airship can be slipped from the mast with safety in any weather.

(*d*) It is easy to standardise it for a number of different sizes and shapes of airships.

Disadvantages.

(*a*) Difficulty of carrying out repairs to the outside of the airship while moored, probably common to all types of mooring mast.

(*b*) Strain on personnel if long periods of mooring are carried out, also common to all types, and can be largely overcome by having duplicated crews.

(*c*) Danger of airship being driven down by snow.

Stub Mast

Advantages.

(*a*) Certain types of repairs are probably more easily carried out than at a high mast.

(*b*) Airship not so likely to be driven down by snow as at a high mast (see (*c*) below).

(*c*) A temporary mast of this type is more easily erected than a temporary high mast.

Disadvantages.

(*a*) A full sized landing party is still required.

(*b*) Ship cannot slip in bad weather without risk of damage.

(*c*) Standardisation of height of mast and diameter of tracks very difficult without putting serious restrictions on the airship designer both as to size and shape.

(*d*) Landing cannot be attempted in bad weather.

(*e*) Snow or frost may interfere with the free running of the trolley, which would bring excessive and dangerous loads on the ship's structure. This may be a more serious danger than that of being driven down by snow when moored at a high tower.

There is little doubt the United States Navy authorities intend continuing their stub mast experiments, and we shall watch the results with interest, but unless some new factors arise, we cannot see any necessity to modify the mooring policy as at present being developed in this country.

A number of other systems of mooring have been proposed, and most of these systems have been dealt with in the paper I have already referred to written by Professor Krell. I would particularly like to refer to the part of this paper in which he discusses an American invention of a Mr. Mason. He says, referring to this invention, "Since similar ideas are often put forward, discussion of his suggestions is not uninteresting."

The invention consists of mooring an airship to a raft either rotating about the forward end on rails or floating in water and moored by the bow so as to allow it to swing to the wind.

Professor Krell says of this invention, "The airship, together with the rotary platform, form a unit too heavy to adjust itself automatically to the wind, hence mechanical power becomes necessary. If a gust of wind suddenly appears from an unexpected quarter, and strikes the side of the airship, no attachment is capable of keeping it from breaking, since it is fixed to the platform, so that it cannot yield in the same way as if it were moored to a mast."

I feel that Professor Krell has hit the nail on the head, and stated in different words the axiom laid down at the beginning of this paper on the controlling factor in any system of handling or mooring, and I am sure he would agree with me that any system of mooring, unless the airship is completely sheltered from side gusts, or can swing freely to the wind, is doomed to failure.

In my last paper I gave a very brief description of the mooring tower being erected at Cardington. This tower has been completed for some time, and the R.33 made a landing to and was moored to the tower on the occasion of the visit of the Dominion Prime Minister in 1926.

The mooring tower in Egypt is also completed, and two new towers, one in India and one in Canada, are nearing completion. In these two latter towers, although the principle of mooring is unaltered, the mechanical details of the head are an improvement on the Cardington and Egyptian towers, the head

being operated pneumatically. A general description of the two systems is given in the appendix.

There is one other aspect of handling that I have not yet mentioned, and that is bringing an airship from the tower to the shed, and the reverse.

Once the airship is on the ground and in the hands of the landing party, the process is the same as discussed under "Handling on the Ground." The new problem is bringing the airship from the tower into the hands of a landing party, or from the landing party on to the tower.

As this manœuvre is only carried out when the weather is suitable for handling the airship either into or out of the shed, it is a fine weather manœuvre, and only necessary in light winds.

If we first take the method employed in manœuvring the airship from the landing party on to the tower.

The airship is walked up to a position to leeward of the tower with the nose of the airship 400 to 500 ft. away from the tower. The main wire is connected to the main tower wire, and yaw guys attached to the tower ground wires led through suitable yaw guy blocks, chosen in the same way as if the airship intended landing to the tower. The slack in all wire is then taken up on the winches and the airship ballasted light is allowed to rise slowly by the landing party walking in on their guys until the airship is controlled by the tower wires. These are then let out until the airship rides on these wires in the same position as if she had made a landing to the tower, and from there on the procedure is the same as for a landing.

In order to take an airship off the tower the yaw guys and main wire are attached and all slack taken up, the catches on the tower are then released and the airship allowed to leave the tower by paying out all wires slowly; when well clear of the tower the trail rope is dropped and manned by the landing party as for a ground landing. The airship is then hauled down by the landing party, the yaw guy winches assisting as far as possible in hauling down and in steadying the bow of the airship against side motion.

This method has proved quite satisfactory in this country, and provided a landing party is to be used, it is doubtful whether any more mechanical method is necessary.

Mechanical methods of carrying out this operation have been suggested and one of these methods was incorporated in the Ford Mooring Tower erected at Detroit. The method, however, introduces considerable complications into design of the tower, and is apt to adversely affect the tower head for normal landings to the tower.

There is no doubt that if it was desirable to carry out this manœuvre in bad weather, a mechanical method would be required, but as long as the limitation of handling in and out of the shed exist, a mechanical method is not considered essential.

There are a number of questions closely associated with the handling and mooring that come just outside the scope of this paper, one of the most important being the choice of a locality for a base. This choice is largely controlled by meteorological considerations.

There are also a number of other problems connected with handling and mooring, but the time at my disposal will not permit me discussing them in detail.

Two, however, of these problems should be mentioned. The effect of snow on an airship when moored and the effect of ice formation or glazed frost.

With regard to snow, although we have had a certain amount of experience of an airship moored in snow squalls, as far as I am aware no airship has been moored out during a heavy fall of snow, and although methods of sweeping

the snow off the top of the airship have been suggested, and I feel that such a device can be developed in the immediate future, it will probably be necessary for an airship to slip and fly in the event of a heavy snow fall occurring while she is moored.

The question of a glazed frost is rather different; it is of rare occurrence in this country, but not uncommon in Canada or the United States, and the amount of ice that an airship would pick up in a glazed frost is difficult to estimate, but from the report issued by the Bureau of Aeronautics, Washington, on the ice picked up on aeroplanes, it would appear as if very little, if any, ice collects on plane fabric surfaces, or bag heat conductors, the heavy coating of the ice collecting on the metal surface, and in an aeroplane, by collecting on wires and struts, so increase the head resistance of the aeroplane that she is forced down, and it is possible that in an airship almost completely fabric covered the amount collected may be slight, and as she does not depend on her forward speed to maintain height, any increase in head resistance does not constitute a danger.

But nothing but actual experience is going to answer many of these questions, and I sincerely hope before the end of the year we shall have had a fair amount of experience and solved some of these mooring and handling problems.

Discussion

The President: No one had greater knowledge than Major Scott of the handling of such great airships. Recently the members of the Society had enjoyed a lecture by Mr. Wallis, the designer of the R.100, which is under construction at Howden, and on April 18th next Colonel V. C. Richmond, the designer of the Government airship R.101, would give an address dealing with this ship. Thus, the ground would be fairly adequately covered by those who were best fitted to discuss these two ships.

Colonel V. C. Richmond: Speaking from the point of view of the designer of airships, he agreed thoroughly with Major Scott's main proposition that the chief limitation in any system of mooring was the amount of concentrated load that could be borne at one point of an airship. The nose of R.101 was designed to stand a load of 30 tons in any direction, and no other point in the hull structure could withstand a load of that magnitude unless it was reinforced a great deal. Therefore, he agreed with Major Scott's contention that it was most logical to "catch hold of the beast" by the nose. He emphasised another point which had been mentioned at previous meetings of the Society, namely, that in any system of mooring which tended to restrict the motion of the ship, forces much greater than the 30 tons he had referred to might very well be imposed upon the ship; in fact, it was now known that even if systems were adopted which allowed an airship to swing into the wind, very large forces might be imposed upon the ship during the process of taking up its direction in a veering wind. As in the case of so many other engineering developments, this problem was almost as much one of finance as of technique. Recently, when at the docks, he had watched a 20,000-ton liner getting away from its mooring and through the locks, and could not avoid making certain comparisons. The process was a very cumbersome one. It had taken far longer than any airship had ever taken to land, so far as he knew, and, of course, he had been impressed by the magnitude of the capital locked up in harbours, quays, piers, lighthouses, etc., for the world's shipping. Sea-going ships had had a great advantage over airships, in that they had undergone development at a time when there was no alternative means of overseas communication. People had had to build ships and to provide means of handling and mooring them, or they had had to stay at home. On the other hand, airships had to be developed at a time when alternative means of transport were definitely established. He personally believed that if the same

amount of capital had been expended on airships as had been expended on the shipping of the world, and the provision of harbours, etc., the airships could achieve the same number of ton-miles as the sea-going ships in less time. That was merely a speculation on cost, and an excuse for the comparatively small expense—as he believed it to be—of the mooring mast.

The PRESIDENT: Inasmuch as this problem of the handling of airships was so largely bound up with meteorology, the meeting would be glad to hear the remarks of Mr. Giblett (of the Meteorological Department), who had previously lectured to the Society, and who had devoted himself entirely for some years to a study of the meteorological situation in connection with airship routes.

Mr. GIBLETT: He emphasised Major Scott's remarks as to the importance of temperature conditions in connection with both the landing and mooring of airships, and exhibited four lantern slides indicating some of the work of the Meteorological Office in connection with this problem at the sub-tropical base at Ismailia (Egypt), where temperature conditions were more important than in this country.

The first slide was a view of the base at Ismailia, showing the mooring tower, which is 200 ft. high, and another tower of similar height a little distance away, on which were installed electrically recording thermometers for the purpose of giving continuous records of the temperatures at various levels. Cables were run underground from this special tower to the meteorological office at the base so that the records were obtained where they were required. The records were being collected so that they would be available for study here, and they could also be transmitted to an airship in the air by radio telegraphy direct from the meteorological office.

The second slide showed the interior of the meteorological office, in which the recorder was situated.

The third slide was a closer view of the special mast, on which were placed thermometers at levels of 4, 50, 150 and 200 ft. respectively above the ground. The records, said Mr. Giblett, contained a curve indicating the actual temperature at the 4 ft. level at any moment, and three other curves indicating the number of degrees difference in temperature as between the 4 ft. and 50 ft. level, the 50 ft. and 150 ft. level, and the 150 and 200 ft. level respectively. It was very largely the difference of temperature as between those levels which affected the condition of the airship when mooring. The records indicated another difficulty which must be considered when comparing the relative merits of a stub mast and a high mast. An airship moored to a stub mast would lie partly in the layer between 4ft. and 50ft. and partly in the layer between 50 ft. and 150 ft., whereas an airship moored to a high mast would lie partly in the layer between 150 and 200 ft. and partly above 200 ft.

The fourth slide showed a specimen record extending over a period of 24 hours, from 11 a.m. on one day to 11 a.m. on the next. This record indicated the vast difference in the temperature conditions at different heights, and the unsteadiness of the temperature in the daytime as compared with the night. At one part of the day there was a difference of 2 degrees in the temperature as between the 4 ft. and 50 ft. level, the temperature being lower at the 50 ft. level; that difference resulted in the air being very unstable, and an airship in that air would be very unstable. As evening approached, the temperature decreased, and there was a fairly long period during which the thermometer at the higher level showed that the temperature was higher there than at the lower level, *i.e.*, there was an inversion of the conditions, and that was very favourable for an airship landing. The variation of temperature as between the 50 and 150 ft. levels was smaller, and there was less inversion than in the lower layer. In the top layer, between 150 and 200 ft., there was a very much smaller difference than in the bottom layer, the curve being very near the zero line the whole time.

The fact that temperature variations were much less extreme in the top 50 ft. than in the lower layers was a very important consideration when comparing the high mast and the stub mast; an airship moored to a high mast was in more stable air than an airship moored to a stub mast.

Captain BOOTHBY: He disagreed with Major Scott's remarks with regard to sheds, and pointed out that when the Naval airships were built, a single-ended shed, facing south-west, had been erected at Cardington, but the Admiralty had never built another single-ended shed. Similarly, the Army had at first used a single-ended shed, but had never built another. All the sheds built during the war were double-ended. Reference had been made in the paper to the British tendency of putting airshps into sheds from the weather end, but he did not think that that was a British tendency. During 1918 airships had flown a great deal more than they had during the last ten years; indeed, during the last ten years airships had not flown so much as they had flown in ten days during 1918, and in that year there were a lot of airship sheds having double doors. Of probably 5,000 landings made in 1918, there were not 50 cases in which ships had been put into the sheds from the weather ends. If the weather door of a shed were open, the wind entered the shed, so that it was necessary to have many people standing by the ship, and there was general discomfort throughout the whole place. The drawings produced by Professor Krell of the eddies at the lee end of a shed looked very nice, but it would be interesting to know how he had arrived at them. If one watched the eddies behind a shed during a snowstorm one would find that they were all over the place, and that to a very large extent they cancelled themselves out. He could not understand why a shed should have doors at only one end, which meant that we should be still in the same position as we were in twenty years ago. It had been stated in the paper that no system of mechanical handling had ever been used in this country, but he would have thought that this was the one country in which attempts had been made to handle mechanically. It was unfair to subject the handling party to the risk of being carried away, and those concerned with the handling of airships had always attempted to use a lorry or anything else they could get. Major Scott would probably remember an occasion upon which his ship was handled into a shed at Howden by means of two old tractors. Probably they had not done the ship any good, but it would not have been put into the shed without these mechanical aids. Later on, at Pulham, a Mark V tank was fitted with a stub mast, but the difficulties experienced, due to the unevenness of the ground, were exactly as stated in the paper. At the same time, he believed that when that system was properly developed, with the mast fitted to trolleys on rails so that it would not sway, it would be found to be the right system for handling airships. He agreed with Major Scott that airships would require more astern power. In the course of the discussion on the paper presented to the Society by Wing-Commander Cave-Browne-Cave, on the machinery installation of the R.101, he had expressed the view that it was criminal to depend on one engine only for astern power that had to be started up on heavy oil when required, because it was very often difficult to start engines. With regard to the stub mooring mast, for the invention of which Major Scott had given the Americans the credit, he said that this was really the mooring mast introduced by Admiral Sir Reginald Bacon for Naval Airship No. 1 at Barrow. Finally, Captain Boothby emphasised the importance of being able to moor an airship over water. He personally believed that we should not have airships used commercially until they could be moored to a buoy in a reasonable harbour, and he was of opinion that it could be done.

Wing-Commander T. R. CAVE-BROWNE-CAVE: This paper was one of a series on airship mooring and handling, and might therefore include a bibliography of all the other papers and important articles published to date. After seeing the diagrams

prepared by Professor Krell, it occurred to him that the eddies might be reduced by a method which would appeal to Mr. Handley Page. By sliding the doors still further out from the shed so as to allow a certain amount of air to pass between the edge of the shed and the edge of the door nearest to the shed, the eddies at the lee end would be reduced as had been done by opening the weather doors and allowing a certain amount of air to go through the shed. This " slotting " method would avoid the trouble which Captain Boothby had mentioned. Referring to the tests of the mooring trolley at Kingsnorth early in the war, he said he believed they were the biggest experiments that had been made in this country on mechanical handling gear. The trolley was wrong because the ship was held, not at the bow, but at a point a considerable distance aft, and far below the axis. Any side force on the ship did not tend to swing her quickly into the wind, but it caused her to roll badly. The experiments had failed, and the envelope of the airship had been torn, because it was extremely difficult to get the side trolleys to move forward at the same pace as the main trolley. He hoped Major Scott did not suggest that those experiments represented Kingsnorth's only contribution to the art of mooring. A point which had been established there for the first time, he believed, and which was of such great importance that it might well be stressed further than in the lecture, was that although, in one's primitive ideas of the requirements of mooring, one always considered a wind right ahead, it was the sudden side gust against which precautions must be taken. This was proved in the tests with the mast, designed by the military authorities, which had a large cone at its head, into which the nose of the ship was fitted. The cone was pivotted about a point some distance ahead of the actual point of the ship. This was quite satisfactory so long as the wind was right ahead, but in a sudden side gust the cone tended to move about its point of support and there was a tendency for the ship to bend its nose in the cone. The result was a very severe bending action on the nose of the ship although it looked as though she was trying to push her nose up into the cone.

In relation to airship machinery, he did not doubt that the requirement for astern thrust was a necessary one, but he drew attention to the fact that it alone was responsible for the necessity of providing variable pitch airscrews or astern gear boxes. Both of these were pieces of mechanism of considerable weight and complexity, and were devices which one would very gladly leave behind. A point which had not been mentioned by Major Scott, or, he believed, by other lecturers, was the importance of being able to determine the force with which the bow of the ship rested on the mooring mast. It was absolutely necessary to ensure the correct trim of the ship before she left. He drew attention to the desirability of an airship being able to ride to a single wire. Under certain circumstances it might be convenient to tie up to any ship's mooring buoy or other anchorage or to be taken in tow. It might be difficult to re-fuel or to pick up passengers when so moored, but it seemed to be desirable to develop a method by which a ship could ride to a single wire and wait if necessary.

Squadron-Leader A. H. Wann: He had handled R.34 practically every time she was taken into or out of the shed, and had also handled her when she had broken up on the landing ground at Howden. In reply to Captain Boothby's remarks, he pointed out that the ship was broken up in an attempt to get her into the shed on the lee side; previously she had been taken in on the weather side without difficulty. The decision to take her in on the lee side on the occasion in question was come to because the wind was blowing practically a full gale—at about 45 m.p.h.—and the opening of the doors at the weather end would have endangered the safety of R.32, which was already in the shed. It was interesting to note that the R.34 was handled along the landing ground for about half a mile, but when approaching the shed, and within a distance of from a quarter of a mile to 300 yards in the lee, the ship became absolutely unmanageable.

The wind was eddying, not so much in side gusts as in vertical gusts; one gust caught the nose of the ship and ground her into the earth. He believed that after the experiences of 1918, 1919 and 1920, during which years a good deal of use was made of airships, every pilot became convinced that the weather side was the proper side to use. Commenting on Captain Boothby's remarks with regard to the invention of the stub mast, he said the Americans had done a lot of work in connection with airships and the handling of them, and he deprecated disparaging remarks in respect of a nation which had made greater allowances to airship services than this nation had.

A SPEAKER: He asked for more information as to the size of the landing parties necessary to handle large airships such as the R.100 and R.101, because the larger the party the greater the difficulty of controlling it. Eight men did not pull a rope eight times as hard as one, and the slightest difference in the pull of the ship made a tremendous difference. One was still dependent upon the human element; the matter of the personnel was a serious one, and he was full of dread with regard to some of the difficulties that might arise in gusty weather.

Commander NORWOOD: After the German Graf Zeppelin had passed Bermuda last year on her journey across the Atlantic a telegram was received at Bermuda ordering that preparations be made to receive and moor the ship within two hours, and that a three-point mooring be prepared for the purpose. He personally had never heard of a three-point mooring for an airship before, and he asked Major Scott if there were any form of mooring which could be prepared at short notice, or what form and size of mooring could have been provided in Bermuda at any time. It had happened that on the occasion referred to the ship had been able to continue her journey to Lakehurst, but the receipt of the telegram at Bermuda had placed those concerned in a difficult position for the time being. It was very desirable that some method of mooring an airship over the water should be developed, particularly if airships were to be used for the trans-Atlantic routes—and it appeared at the moment that they would be used mostly for long overseas flights. He had wondered whether some form of floating dock, with mooring masts, could be used; such docks could be sunk if necessary, and raised after the airships had been moored.

Mr. SCOTT HALL: The problem of getting the airships into and out of the sheds from the aerodynamical point of view, it would appear that the proper end was obviously the weather end, especially if shutter doors were used, because the ordinary doors standing out on either side of the shed, either at the lee end or the weather end, would produce very great eddying. If there were shutter doors (sliding along the sides of the shed) at the weather end, the emerging ship and the shed combined would produce a streamline form. That was important. He asked if experiments had been conducted in which a ship had been taken out of a shed with the doors at both ends open. It seemed that if the doors at both ends were open, the shed would form more or less a tunnel, and that the air travelling through that tunnel would be very much less disturbed than would be the air in a shed closed at one end and having an opening at the other end varying in size as the ship moved in or out. Referring to a photograph exhibited by Major Scott, of an American airship moored to a stub mast, with the rear car of the ship secured to a trolley or weighted bogey to prevent vertical motion of the tail of the ship, he asked what weight was necessary on the bogey. He pointed out that the members which held the car to the ship were very long and were obviously designed only for tension, but it appeared that considerable weight would be required to keep the ship down to the ground, and that then they would be subjected to compression for which they seemed totally unfitted.

Mr. SPANNER (*Contributed*): He was sorely tempted to recall to Major Scott's mind certain of the optimistic statements, in regard to the mooring and handling

of rigid airshps, which he made at a time when every effort was being made by rigid airship enthusiasts to embark this country on an expensive rigid airship programme—incidentally a programme which has far exceeded all estimates both as to cost and time required. He would like to note the following from this present paper:—

1. "It is my personal opinion that the airship pilot of the future will look with horror at the idea of landing to a landing party and a manœuvre only to to be carried out in cases of extreme urgency."

2. "It is my personal opinion that with the large airships of the size of R.100 and R.101 and upwards, it will be practically impossible to handle them on the ground or in and out of the sheds, except in light winds whose direction is up or down the shed, and not at all in winds that have any appreciable component across the shed."

3. "The new problem is bringing the airships from the tower into the hands of a landing party, or from the landing party on to the tower. As this manœuvre is only carried out when the weather is suitable for handling the airship either into or out of the shed, it is a fine weather manœuvre, and only necessary in light winds."

The above extracts might have come from his own expressed opinions on the subject; he was not too sure that they hadn't. He congratulated Major Scott on his frankness. It is a pity he did not express such opinions very much earlier.

Major Scott goes on to tell of the impossibility of repairing the outer cover at a mooring mast. He was surprised that Major Scott did not make it equally clear that it would be quite impossible to replace an important gas bag, to effect any replacement of important structural members, to effect any extensive re-adjustment of the main wiring, or to contemplate the total removal of an engine car—seeing that it is now recognised that the advent of bad weather would render it imperative that the airship be freed from the mast to fend for herself.

Surely Major Scott cannot possibly continue to think in as rosy terms as he did in 1922 and 1923 of the prospects of making rigid airships a commercial success. A very grave responsibility rests with those who are advising the Government in this matter.

Reply to Discussion

Major Scott: He thanked Mr. Giblett, in the first place, for having illustrated the temperature charts obtained in Egypt. He agreed that when there was an inversion, *i.e.*, when the temperature increased with height, the conditions for landing and for mooring were ideal, and no trouble whatsoever was encountered. The chart exhibited—which was typical of the charts obtained in Egypt—showed that the bad conditions, *i.e.*, the conditions in which there was a heavy gradient, occurred for only about 6 hours of the 24, so that for the greater proportion of the day and night, even in a country such as Egypt, the conditions for landing were excellent. That was one of the points that had been learned from the experiments, and we were learning more as records became available.

Replying to Captain Boothby, he said he still held that the proper door through which an airship should enter or leave a shed was the weather door. He believed difficulties had been experienced during the war due to the use of wind screens, which became an obstruction whatever door was used, but those screens were not used now. If he had given the impression that no experiments had been carried out in this country in the direction of mechanical handling, he had done so quite unintentionally. What he had intended to say was that no accepted system, such as the handling rail system, had been adopted, and that we were still handling airships on the ground by man power. He did not think the very big ships could be handled in and out of the sheds in any appreciable wind; they could be handled in and out of sheds only in very light winds, and it was the

realisation of that limitation that had led to the development of the mooring tower. The idea at present was that the airships would always land at the mooring tower, and would have to await an opportunity to be handled into the shed. They might perhaps have to wait a couple of days on occasions. In 1921, however, when a lot of experiments were carried out, only on one occasion had it been necessary to wait for more than 24 hours for an opportunity to get a ship into a shed.

The landing party necessary for handling these large ships would comprise probably 400 or 500 men. That was a rather large party to control, but he hoped that the ships would not be handled in and out of the sheds more often than was absolutely necessary. He agreed that the control of a handling party of 400 men was a difficult matter, and requiring organisation.

With regard to mooring on the water, during the war quite a number of experiments were carried out in the direction of using a rope and a drogue. In some experiments with the R.9 or R.23, a motor launch had been used and had attached the drogue from the airship to a buoy, and the ship had remained there for several hours. These experiments were carried out in the Wash. There was no doubt that a system could be developed by which an airship could ride on a single wire at a height of probably 1,000 ft. on a drogue, and, he believed, could even drop her own anchor and take it up again without assistance from outside. A drogue was carried always as standard equipment. No airship in this country was allowed to fly without one, because if she ran short of fuel when over the sea the correct thing to do was to descend and to ride at the drogue so as not to waste ballast or fuel, and then to wireless for assistance. The long rope could also be used for towing. A sea-going vessel could tow an airship to a point near the coast, and the airship could then cast off and fly to the nearest landing ground, sufficient fuel having been retained for that purpose. The limitations of such a system of mooring were that an airship could not re-fuel or re-gas while so moored.

The three-wire mooring, mentioned by Commander Norwood, was an emergency mooring. The idea was that if one wanted to provide some means of holding an airship without incurring too great an expense and without having to maintain a landing party permanently, a three-wire mooring could be provided. An airship could ride on these wires, but could not be easily re-fuelled or re-gassed when so moored. The airship in which he had flown to America, however, was moored in that way for four days, but was re-fuelled by landing down into the hands of a handling party.

He agreed with Wing-Commander Cave-Browne-Cave that it was necessary, before leaving the mast, to ascertain what pull the ship was exerting on the mast. It was necessary to have a device on the bow to show what was the pull exerted by the mast on the bow, and it was useful also to have an indication of the side pull, so that one could determine what stresses were imposed upon the ship in gusty weather. The necessary devices were being fitted.

Replying to Mr. Scott Hall, he said he did not remember an occasion upon which a ship had been taken into a shed when both doors of the shed were full open, though he would not suggest it had not been done. Dealing with the question as to the weight on the trolley secured to the rear car of the airship moored to the stub mast, he said that one would have to vary the ballast in an airship even on a stub mast, because the variation in the lift of the ship as between day and night varied by many tons, especially when the days were hot, but the weight referred to would probably be kept down to two tons. He believed the struts shown in the photograph were temporary, because there was a possibility of a side push being imposed on the car and the struts prevented the car from tipping over. He believed they were taken out when the ship was in flight.

PROCEEDINGS

Eleventh Meeting, Second Half, 64th Session

In the Chair:

THE PRESIDENT, COLONEL THE MASTER OF SEMPILL

The above meeting of the Royal Aeronautical Society was held in the Rooms of the Royal Society of Arts, John Street, Adelphi, W.C.2, on Thursday, May 9th, 1929.

The President: The last lecture they had the pleasure of listening to from Captain Tymms was on the practical navigation of aircraft, a subject on which he was well qualified to speak, as he had specialised on it for the past ten years or so. Captain Tymms had recently come home from East Africa, where he had been the Air Ministry Superintendent of the Cairo-Karachi line, or Cairo-Basra line, as it then was, to take up the post of Technical Adviser to the Director of Civil Aviation. The subject of the lecture was one on which he was very qualified to speak, because he had been all through the territory for the Air Ministry.

PROSPECTS OF CIVIL AVIATION IN EAST AFRICA

BY

F. TYMMS, M.C., A.F.R.Ae.S.

Introduction

Having clearly in mind the nature of the papers usually read before this Society, it was a rather overwhelming prospect which confronted me when I was asked to read a technical paper on that which, as yet, hardly exists. Turning the subject over in my mind, I came to the conclusion that, while the contribution to the science of aeronautics must be nil, yet as a means of focussing attention on one aspect of future development, the paper might not be without its uses to British aviation. It will be clearly understood therefore that the paper, in the ordinary sense of the word, cannot be made technical, while it will stray into the realms of geography, both physical and economic, geology, agriculture and climatology. All these are fit subjects for the consideration of the prospective pioneer of commercial aviation in a new territory.

This paper has arisen from a tour made through the Sudan, Kenya, Uganda and Tanganyika from January to August, 1928, when I was seconded to the governments of the three last-named territories for duties in connection with civil aviation. My itinerary involved travelling from Cairo to Lake Victoria by way of the Nile valley, and journeys, mostly by car, to the extreme west and south-west of Uganda, and the extreme south of Tanganyika, as well as the better known coastal and highland regions of Kenya and Tanganyika. While I had not the advantage, except rarely, of using an aeroplane to assist in my work, the results obtained by ground observation, though naturally lacking the useful, broad, mass treatment of aircraft observation, gain something in detail.

THE COUNTRY

Apart from the Sudan, which will be referred to later, the three territories—Kenya, Uganda and Tanganyika—are closely inter-related political units, the greater unity of which it is the object of the Report of the Hilton Young Commission* to bring about. It is appropriate therefore to deal with them together. Kenya is a Crown Colony, but the important coastal strip, including Mombasa, is the property of the Sultan of Zanzibar and forms a protectorate of the British Crown. Uganda is a protectorate, but as a fact the protectorate form of government extends only to Buganda proper and one or two other native states, while the rest of the country is administered as a Crown Colony. Tanganyika is a mandated territory of the League of Nations.

The three territories together extend something over 1,000 miles from north to south, and 850 miles from east to west. Of the three, Tanganyika is the largest, Uganda the smallest. Kenya has the largest white population; Uganda the smallest. The following table gives a comparison of some of the outstanding statistics:—

	Kenya.	Uganda.	Tanganyika
Area, square miles	225,000	94,000	384,000
Population, total	2,560,000	3,137,000	4,120,000
,, white	12,500	1,750	5,000 (approx.)
Annual exports	£3,087,000	£2,310,000	£3,440,000
,, imports	£7,571,000	£1,820,000	£3,672,000
Population per square mile	11	33	11
Exports per head of population ...	Sh. 24/-	Sh. 15/-	16s. 8d.
Imports ,, ,, ,, ...	Sh. 60/-	Sh. 10/-	17s. 10d.

Trade

Kenya's activities may be judged by her exports, which, in order of value, are coffee, maize, sisal, hides and skins, and carbonate of soda. All these are of European production, with the exception of hides and skins, which are largely supplied by the cattle herding Masai and other tribes. Uganda's exports consist mainly of cotton, practically all of which is native grown. Tanganyika, in her trade, as in other things, partakes of the nature of the "colonised" Kenya on the one hand and of the almost purely native Uganda on the other. Her leading export is sisal (European), followed by coffee (mainly European), cotton (mainly native), ground-nuts, hides and skins (native), and a small but growing quantity of European mined diamonds and gold.

Extent and Boundaries

The East African territories lie between $4\frac{1}{2}°$ N. latitude and 12°S. latitude, and between $29\frac{1}{2}°$ and 42°E. longitude. Kenya itself is virtually bisected by the equator, but nearly all the centres of settlement and trade lie in the southern hemisphere. The most important neighbour of these territories is the Belgian Congo, which adjoins both Uganda and Tanganyika on the west. The transport systems of all three territories derive benefit from the Congo trade, and it is one of the most important aims of East African development to foster this connection. On the north, the Sudan is a not unimportant neighbour, not by reason of direct trade, but because of the existence of the Nile as a factor in through communications. This factor will become of immensely greater importance with the opening of a regular air service from Egypt to East Africa. Further to the east, Kenya has two northern neighbours in Abyssinia and Italian Somaliland, both cut off by the desert of the Northern Frontier Province from easy intercourse with the settled areas of the country. A little

* Report of the Commission on Closer Union of the Dependencies in Eastern and Central Africa, 1929. (Comd. 3234).

irregular trade in the way of cattle raiding across the Kenya-Abyssinia border is all that is carried on at present. On the south, Tanganyika abuts on Portuguese East Africa, Nyasaland, and Northern Rhodesia, each on account of bad communications on both sides of the frontier, living its life with very little reference to the life of its northern neighbour.

Topography

The main geographical feature of East Africa is the central plateau, which rises in a series of roughly defined steps from the coast. West of the meridian 38°, which passes close to Mts. Kenya and Kilimanjaro, then near Morogoro, the country is practically all above the 1,000 metre (3,300 feet) contour.

In the north-east (Northern Frontier Province and Tanaland) there is a wide area of land below this contour. In the centre (Mombasa to Dar es Salaam), the climb from the coast is rapid, while again in the south-east of Tanganyika the area of lower country extends well to the west of meridan 38°.

This high plateau, which extends right to the western frontier of Uganda, has several distinctive features. It is virtually surrounded by a high rim of land which, while broken in places, has for its main bastions, Mt. Kilimanjaro (19,720 feet) and Kenya (17,040 feet) on the east, Mt. Elgon (14,140 feet) on the north-east, Ruwenzori (16,800 feet) and the Mfumbiro Mts. (14,630 feet) on the west, the Ufipa Plateau in the south-west, the Poroto Mts. and Livingstone Mts. (10,000 feet) on the south, and a series of mountain groups—Iringa, Uluguru, Nguru, Usambara and Pare (varying heights up to 8,000 feet)—completing the east side. The plateau extends in places beyond these limits, principally to the west and south, but these mountains do form a rough limit to the plateau in the East African dependencies.

Most of the mountains of the country lie on this outer rim, but special mention must be made of the extensive mountain mass lying between Mts. Kenya and Elgon in the north-east. This comprises the Aberdare Mts. (13,000 feet) and the Mau Escarpment (10,000 feet) and all the high valleys and plateaux, which form the centre of European settlement, and are known as the Kenya Highlands. The more or less isolated peaks lying to the west and south-west of Kilimanjaro, reaching in several cases 11,000 and 12,000 feet, and in the case of Mt. Meru, at Arusha, 14,950 feet, are also worthy of note.

The second important feature of the plateau is the exsistence of the two Rift valleys. The Eastern Rift Valley, enclosing Lake Rudolf in the north, cleaves through the mountain mass in the north-east, between the Aberdares and the Mau. With a width of 30 or 40 miles it contains a string of minor lakes—Baringo, Hannington, Nakuru, Naivasha, Magadi and Eyassi. The Western Rift Valley lies generally west of the western rim of mountains. It contains a chain of larger and better known lakes—Albert, Edward, George, Kivu and Tanganyika.

The third and most important feature of the plateau is the central depression of Lake Victoria, which lies at a height of 3,726 feet, between the Eastern and Western Rift Valleys. The lakes of the Western Rift Valley are generally about 1,000 feet lower than Lake Victoria. The lakes of the Eastern Rift Valley are, in the north and south, lower, but in the central highlands (Naivasha and Nakuru) 2,000 feet higher than Lake Victoria.

Escarpments, dividing plateau from plain, are a feature of the country almost as common as the ordinary range or group of hills. Lakes having no outlet to the sea, and therefore often salt, are a not uncommon feature, particularly in the southern part of the Eastern Rift Valley.

From the point of view of aviation, one is concerned with the nature of the surface—a feature which varies with type of soil, with altitude, rainfall

and with cultivation. Generally speaking, Kenya contains the largest areas of a type of country suited to aviation, viz., grassland; Uganda is the least suited to aircraft operation, because of its irregular contours; Tanganyika has some good areas and vast areas of level bush on which landing grounds can be readily made.

Forest occurs only in limited areas in all three territories, and generally only on the mountains. At the highest limit, 8,000 to 10,500 feet, bamboo forest is found. Below this, mixed tropical forest occurs. This is also found in isolated areas in Uganda, where the rainfall is high. It consists of very high trees and dense matted undergrowth. Except for the remains in patches of a vast forest, which once covered Buganda on the north and west of Lake Victoria, there is insufficient forest to affect flying conditions in the country.

The next most densely wooded area is the coastal belt, which supports a dense growth of cocoanut palms along its whole length. This strip is very narrow, never exceeding a width of 10 miles.

Savannah forest covers very large areas, particularly in the southern part of Tanganyika. This consists of trees of the acacia and myombo types—*i.e.*, spreading tops, 3in. to 6in. boles, height 20 to 30 feet—and undergrowth varying from barren sand or short grass to low bush. The undergrowth is never dense, and the forest has nothing of the dark heaviness of the tropical forest. Landing grounds can often be made in this country with ease, and very occasionally there are clear spaces where a forced landing may be made. Examples are found extending practically all the way from Iringa to Mbeya, and in many parts of the country mixed with bush.

Bush is the most common feature of the landscape in East Africa. It is almost easier to describe all other types of country as exceptions to the general rule. Bush varies from something akin to the savannah forest with dense thickets of undergrowth, through varying stages to a low thorn scrub which, through lack of water, may go for 12 or 18 months without bearing leaves. Almost without exception all bush vegetation bears thorns. In the lower kinds of bush a machine might be landed with care, in emergency, without doing serious damage. There are frequent semi-open clearings in most bush country. They sometimes occur as large open grass flats (mbugas) along the course of rivers. These are safe to land on, except during and after rains.

Bush, while it covers hills and broken country, occurs frequently in vast, level, unbroken plains, good examples of which are found between the coastal belt and the grass steppe country (near Nairobi) on the Kenya Uganda Railway, practically over the whole of the plateau region of Tanganyika, and particularly between Dodoma and Iringa and Dodoma and Kondoa Irangi.

The Northern Frontier Province is an example of a very large thorn scrub plain, which is so dry that on large areas not even the dry thorn bush grows. The scrub plain then becomes a desert plain.

The densest and most luxuriant growth of bush occurs in the lower country just behind the coastal belt where the rainfall is fairly high. Similarly it occurs along the banks of some rivers.

Grass steppe, or veldt, occurs frequently in the highland region lying between Mt. Elgon and Mt. Kenya, with extensions south from there over the Athi Plains, north and west of Mts. Kilimanjaro and Meru, over the Zerengeti Plateau still further west, and south of Mwanza. Roughly, in all that high part of the plateau which lies between Mt. Kenya and Mt. Kilimanjaro on the east, and Lake Victoria on the west, while bush, savannah forest and tropical forest occur, there is no lack of grassland, in many places level and smooth. It occurs in varying forms, from the flat, grass glades in the forests of the Mau to the rolling grass downs of the country north-west of Mt. Meru.

This area comprises all the more important settled areas of Kenya and Tanganyika, and flying in this region is therefore a comparatively safe undertaking.

Grass country occurs in other regions. One for example is the grass covered mountain area of Ankole in south-west Uganda. Here the slopes are steep, and all level land in the valleys is composed of papyrus swamp, and there are no possibilities of landing.

The topographical features of East Africa have been divided into many different classifications, but these are the principal types as they affect the aeroplane.

To give a broad general description of various zones of country is bound to be misleading if it is taken too literally, but purely as a key to the situation the country can be roughly divided up as follows :—

(1) *Coastal fringe.* Palm trees and mangrove swamps, dense cultivation. An abundance of creeks and river estuaries suitable for seaplanes.

(2) *Between coastal fringe and highlands.* Bush plains interspersed with broken country. Bush very dry in the region of small rainfall. Many boabab trees up to 3,500 feet. In Tanganyika, many grass plains, inclined to be swampy in this zone.

(3) *Northern Frontier Province, Tanaland.* Dry, thorn scrub plain, merging into desert plain.

(4) *Highland region of Kenya and Northern Tanganyika.* Mountains, forest, broken country, much cultivated in parts, but abounding in grass country either in large open plains or downs or in isolated clearings in the forest. Grass plains extending, in the south, to the west over the Zerengeti Plateau and the plains south of Mwanza.

(5) *The plateau region of Tanganyika.* Generally bush and savannah forest, suitable in many places for the making of landing grounds, and in some isolated places opening out to form mbugas (grass flats) which are usually soft in the rains.

(6) *Buganda Province of Uganda.* Patches of forest, elephant grass, bananas, native cultivation, hilly with papyrus swamps in all the valleys. Very densely populated. An unfavourable country.

(7) *Northern and Eastern Province of Uganda.* Bush country, sometimes in flat plains, but many areas of rolling bush. Some grass plains towards the north-west. Rather dry country.

(8) *Karamoja and Turkana* (*i.e.*, the contiguous districts of Kenya and Uganda in the north). Arid country, thorn scrub, isolated rocky hills and plains, either of sand or sparse grass and scrub.

(9) *Western Province of Uganda.* From hilly to mountainous, with many lakes suitable for seaplanes. The valleys are almost invariably choked with papyrus swamps, and only occasionally can a piece of level, dry land be found.

Trade Routes

It will be of interest, before proceeding, to take a glance at the trade routes of to-day and yesterday in this part of Africa. We might even start with one which is still only a dream, to wit, the Cape-Cairo railway. If Cecil Rhodes had lived 20 years later, he would never have dreamed of a Cape-Cairo railway, but only of a Cape-Cairo airway. There is no longer any point in incurring enormous capital expenditure in building a railway to carry express through traffic from the Cape to Cairo. The railway never would have had a

prospect of carrying anything but such express traffic, except locally. The bulk produce of the country must always find its nearest outlet to the sea, along one of the many existing lateral railways. With the advent of air transport it is probable that the Cape-Cairo railway will never now materialise, or that it will be brought about by the linking, for local needs, of the last two unconnected lateral systems, an event the significance of which will probably be overlooked at the time, so little importance will be attached to the economic effect of a Cape-Cairo railway.

The Nile has always been a great north-south trade route, but only intermittently in the last few thousand years has it been open right through to the African lakes. The untamed black tribes of the southern Sudan and the equally untamed morass of the sudd have been sufficient to close it for hundreds, if not a thousand years, at a stretch, until even the memory of the route itself had vanished into the limbo of the past. In modern times, the route was first traversed by Baker in 1863.

The Nile throughout its length to Lake Victoria is now used as a tourist route, but for little else except the local communications of the Sudan and a certain amount of traffic with the north-eastern corner of the Belgian Congo (Kilo-Moto mines area) via Rejaf and Aba.

The main trade routes of the present day are naturally along the three main lines of railway running laterally to the Indian Ocean.

(1) The Uganda Railway, from Jinja via the Kenya Highlands to Mombasa.

(2) The Tanga Railway, from Arusha and Moshi (N. Tanganyika) to Tanga.

(3) The Tanganyika Central Railway from Kigoma on Lake Tanganyika and Mwanza on Lake Victoria, to Dar es Salaam.

The latter carries a certain amount of traffic, both mail and freight and passengers, from the Katanga area of the southern Congo. It is interesting also to note that it corresponds roughly with one of the old slave trade routes to the densely populated Lake Victoria basin, at a time when the Masai and the Kikuyu made the approach via the Kenya Highlands unsafe, even for slave raiders.

The trade routes of the eastern Congo are important to East Africa. The enormously wealthy mineral area of Katanga in the south-east, which is exploited by the Union Minière de Katanga, and which, in addition to large quantities of copper, produces the bulk of the world's radium supply, sends most of its produce out via the Rhodesian railway system. A certain amount goes via Dar es Salaam, but the opening of the Lobito Bay railway to the neighbourhood of Elizabethville, which will shortly take place, will tap all this. While it is possible to get produce to a convenient port on the West Coast of Africa, no shipper will send it to the east coast, whence it has to bear freights doubled or trebled in amount by the incidence of the Suez Canal dues. This carrying trade, therefore, is virtually lost to British East Africa.

The other important part of the eastern Congo—the Kilo-Moto area—has already been referred to. The bulk of its produce finds its way by a tortuous river and road journey to Boma at the mouth of the Congo. The mail and some passengers travel via the Nile, while some passengers travel via Butiaba and the Kenya-Uganda railway. The opening of the air service from Egypt to East Africa will, it is expected, attract many of them to the Nile route.

The Climate

To complete the brief survey of the terrain it is necessary to know something of its climate. Realising the enormous importance of a knowledge of

the climatology of a country to the development of aviation, I offer no apology for the amount of space which follows devoted to this subject.

The seasons in the African tropics are governed by one basic law, which can be traced through sundry local variations, viz., that the rains follow the sun as it swings across the equator from northerly to southerly declination and back. There is a time lag of one to two months between the passing of the sun in its journey north and south, and the period of maximum rainfall, or even commencement of the rains, on the same parallel of latitude. Since, on the equator, the sun passes overhead twice a year, there are two rainy seasons, corresponding to the spring and autumn equinoxes. These occur in April (long rains) and November (short rains).

Approaching the tropics of Cancer and Capricorn, where the sun reaches the zenith only once a year, in June and December, the two rainy seasons merge into one—May to August in the north; December to March in the south. Between the equator and the parallels of $23\frac{1}{2}°$ north and south, the seasons change gradually from the double rains to the single rains—in the northern hemisphere, for example, the long rains becoming later and the short rains earlier until they merge.

The zone of divided rains about the equator is very much narrower than would be expected from purely theoretic considerations. It extends only over a matter of 5° or 6° of latitude north and south of the equator. The limit of the zone is not uniform. In places it is found to extend one or even two degrees further north or south, the differences appearing to depend on variation of local conditions, such as oceanic and continental areas, or mountain and plain.

Whether north or south of the equator, within the "two rains" belt, the rains associated with the northerly passage of the sun appear to be the longer and heavier. Even outside this zone, where the two rains have merged into one, there is found a tendency for the rains to reach a maximum following the passage of the sun in its northerly course, *i.e.*, in March, April or May.

Nowhere in East Africa does the volume of rain reach the enormous total of several hundred inches a year experienced in the same latitudes in West Africa. The rainfall varies from something less than 20 inches in the Northern Frontier Province of Kenya, to 80 or 90 inches, the latter high totals being limited to the isolated areas influenced by high mountain peaks and to the western shores of Lake Victoria.

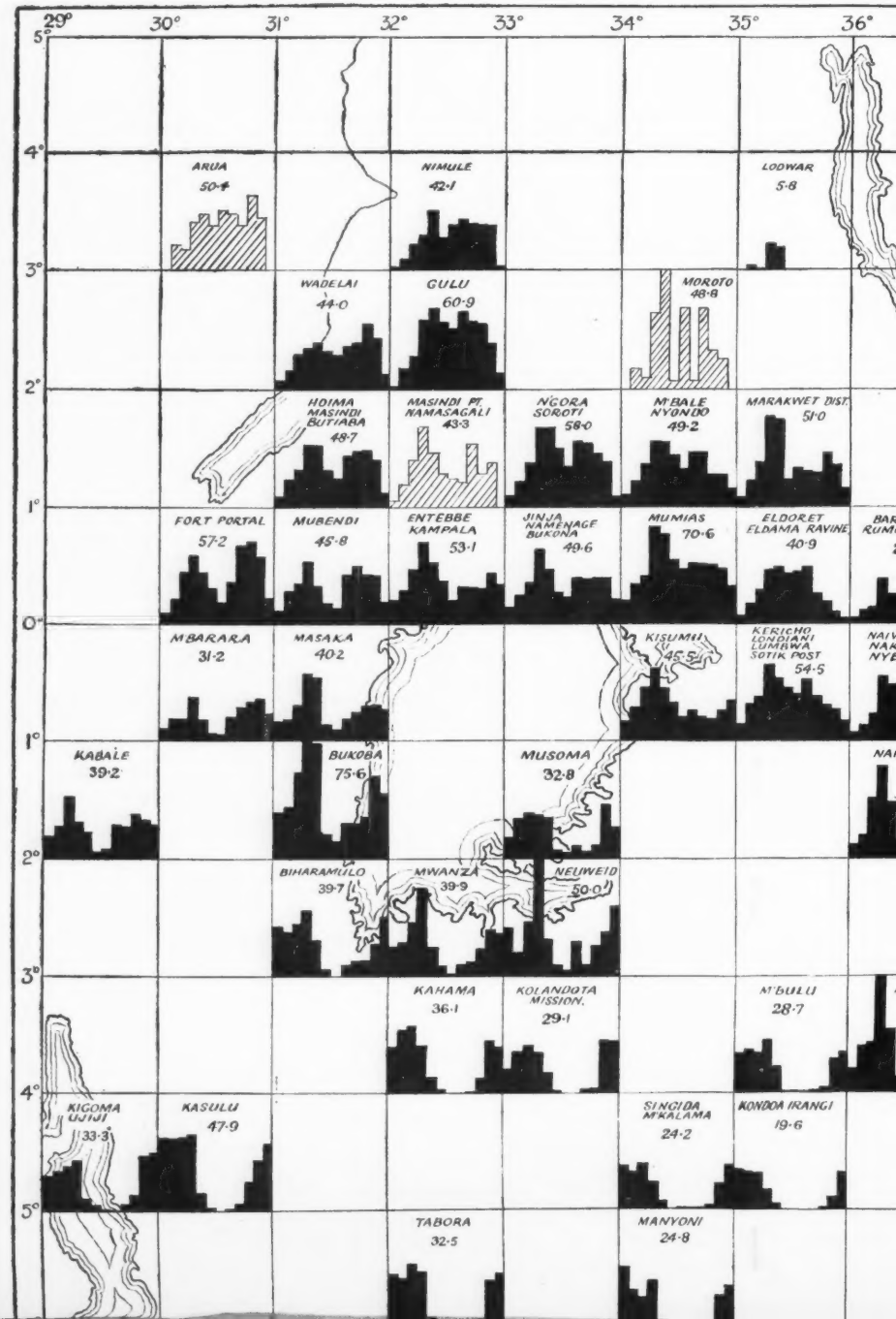
To relate the climate of East Africa to that of the Continent as a whole, one may enumerate the various zones following the Nile air route from Egypt as follows. The Delta of the Nile, with a part of the Nile Valley extending at most 100 miles south of Cairo, is in the region of winter rains, influenced by the depressions of the Mediterranean. On the coast, at Alexandria, the annual rainfall is as much as 8.5 inches, but at Cairo it is no more than 1.2 inches, all of which falls between November and March.

The region between Cairo and Khartoum is virtually rainless, and the country is, in consequence, arid desert. This embraces Assiut, Luxor, Assouan, Wadi Halfa and Atbara.

At Khartoum, in latitude 15°N., one enters the northern fringe of the tropical rain belt associated with the sun. Hence the rains are summer rains—July to September. Owing to the northerly latitude they are undivided rains. From Khartoum southwards the same conditions can be traced to the southern border of the Sudan, with constantly increasing intensity of the rainfall and an earlier start and later cessation. The effect of the change in climate is visible in the vegetation—from the barren plains around Khartoum which, for a month or two in the summer, become green with some quick crop, to the grass plains of Darfur and the Nuba Mountains, the swamp areas of Bahr el Gazal, and finally the forests of Mongalla. Even in this southern zone,

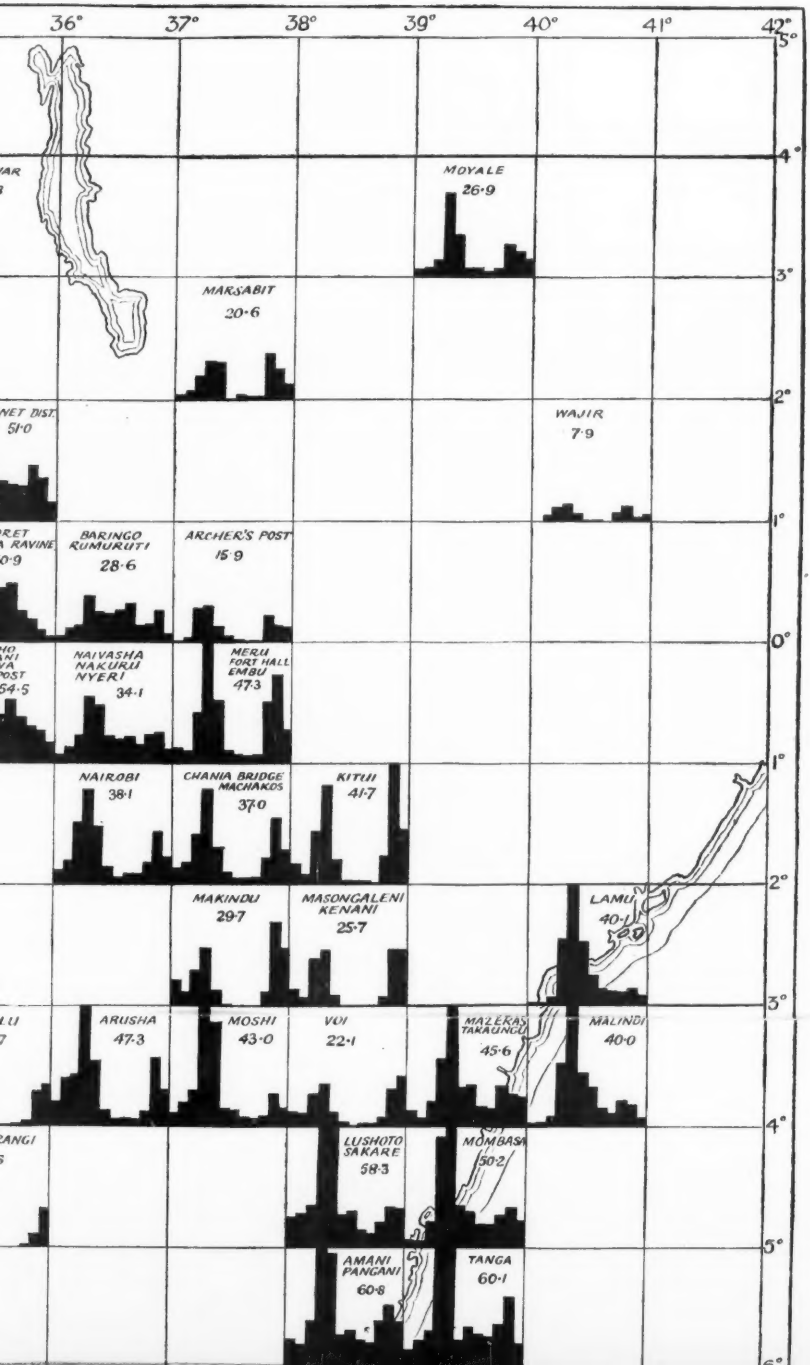
Chart No. 1.

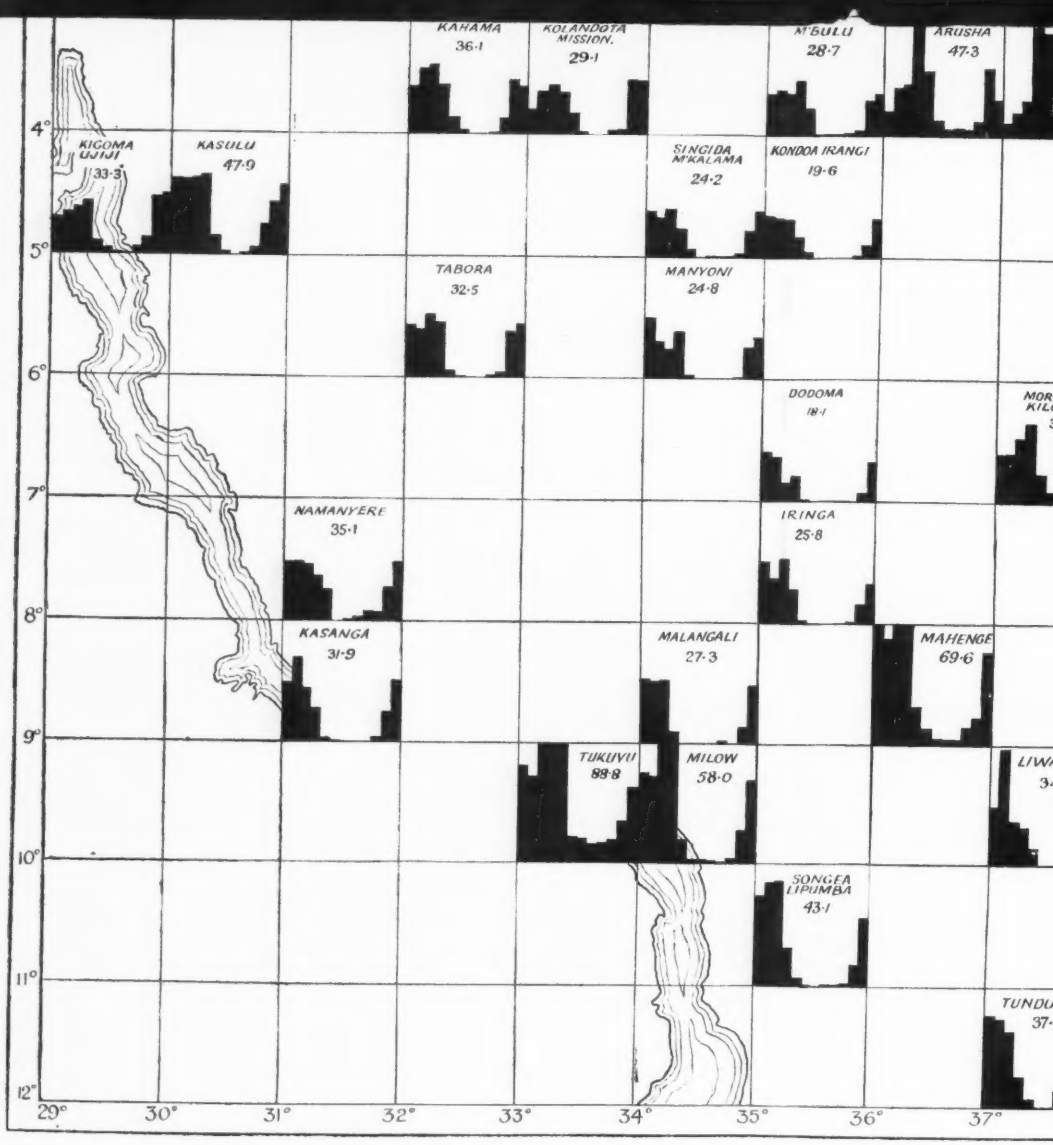
East Africa, Rainfall D



No. 1.

nfall Distribution.




KAHAMA
36·1
KOLANDOTA MISSION.
29·1
M'BULU
28·7
ARUSHA
47·3
KIGOMA UJIJI
33·3
KASULU
47·9
SINGIDA M'KALAMA
24·2
KONDOA IRANGI
19·6
TABORA
32·5
MANYONI
24·8
DODOMA
18·1
NAMANYERE
35·1
IRINGA
25·8
KASANGA
31·9
MALANGALI
27·3
MAHENGE
69·6
TUKUYU
88·8
MILOW
58·0
SONGEA LIPUMBA
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4°
5°
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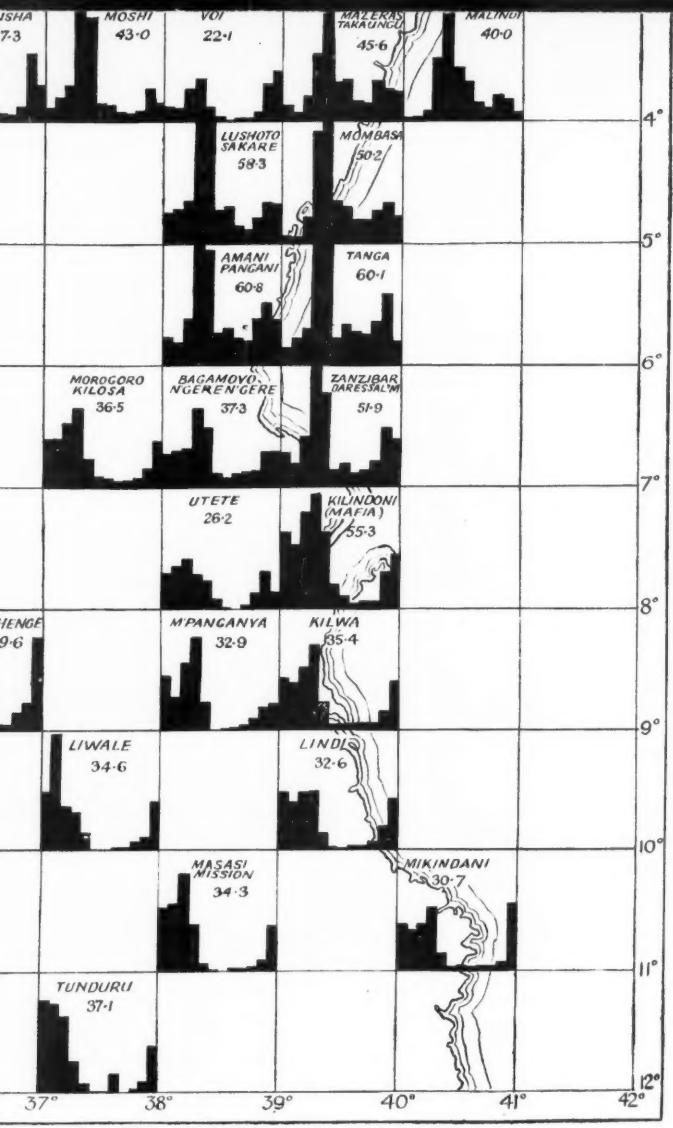
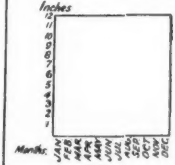


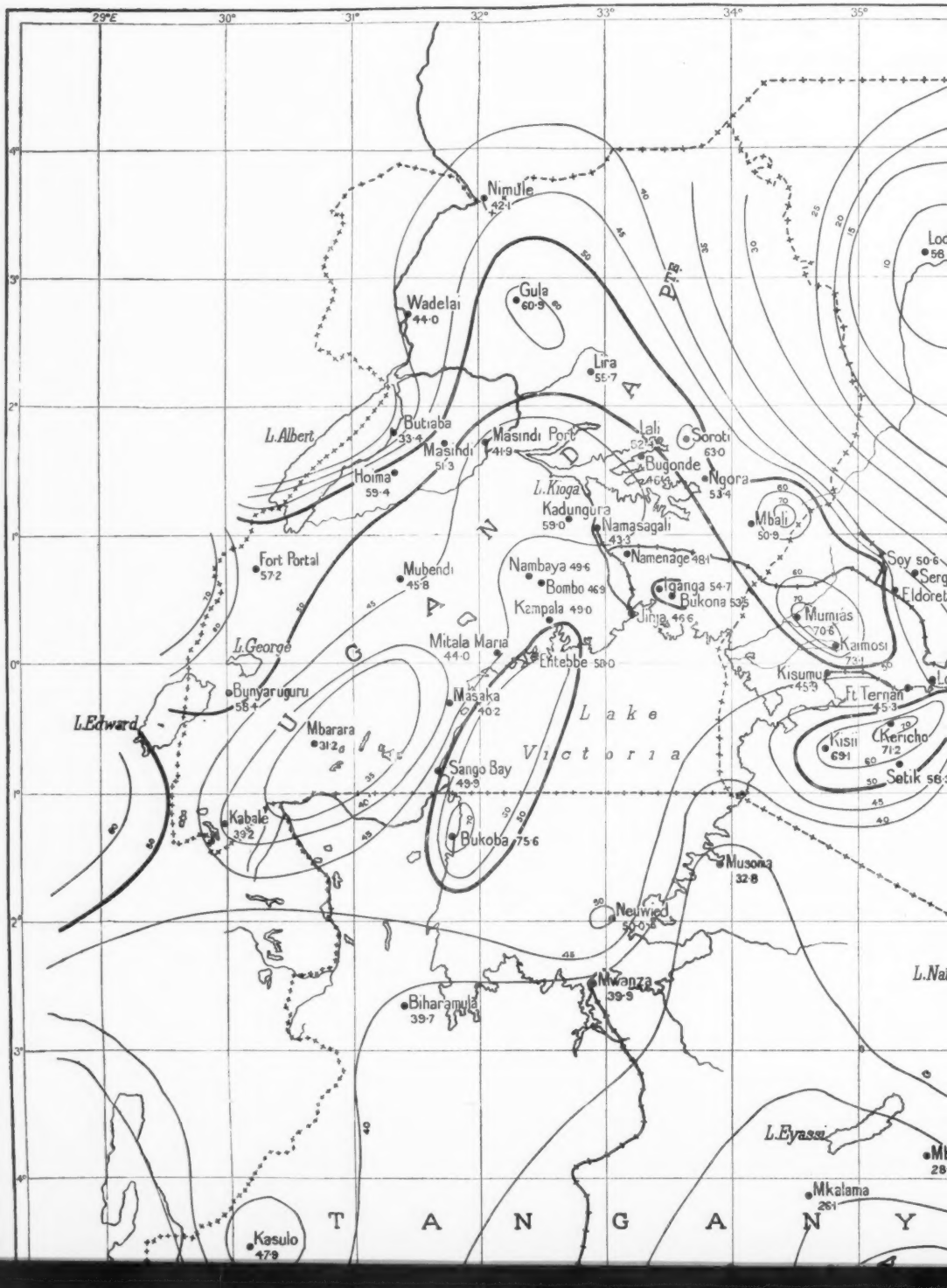
EXPLANATION.



1. The map is diagrammatic. Each square represents 1° of latitude and 1° of longitude.
2. The ordinates represent inches of rain, the abscissæ represent months.
3. In a very few cases the rainfall exceeds 12 ins in a month and the excess over 12 ins is not shown
4. Stations where only one year's observations are available are shaded
5. The names of the stations used with their mean annual rainfall in inches are given in each square.

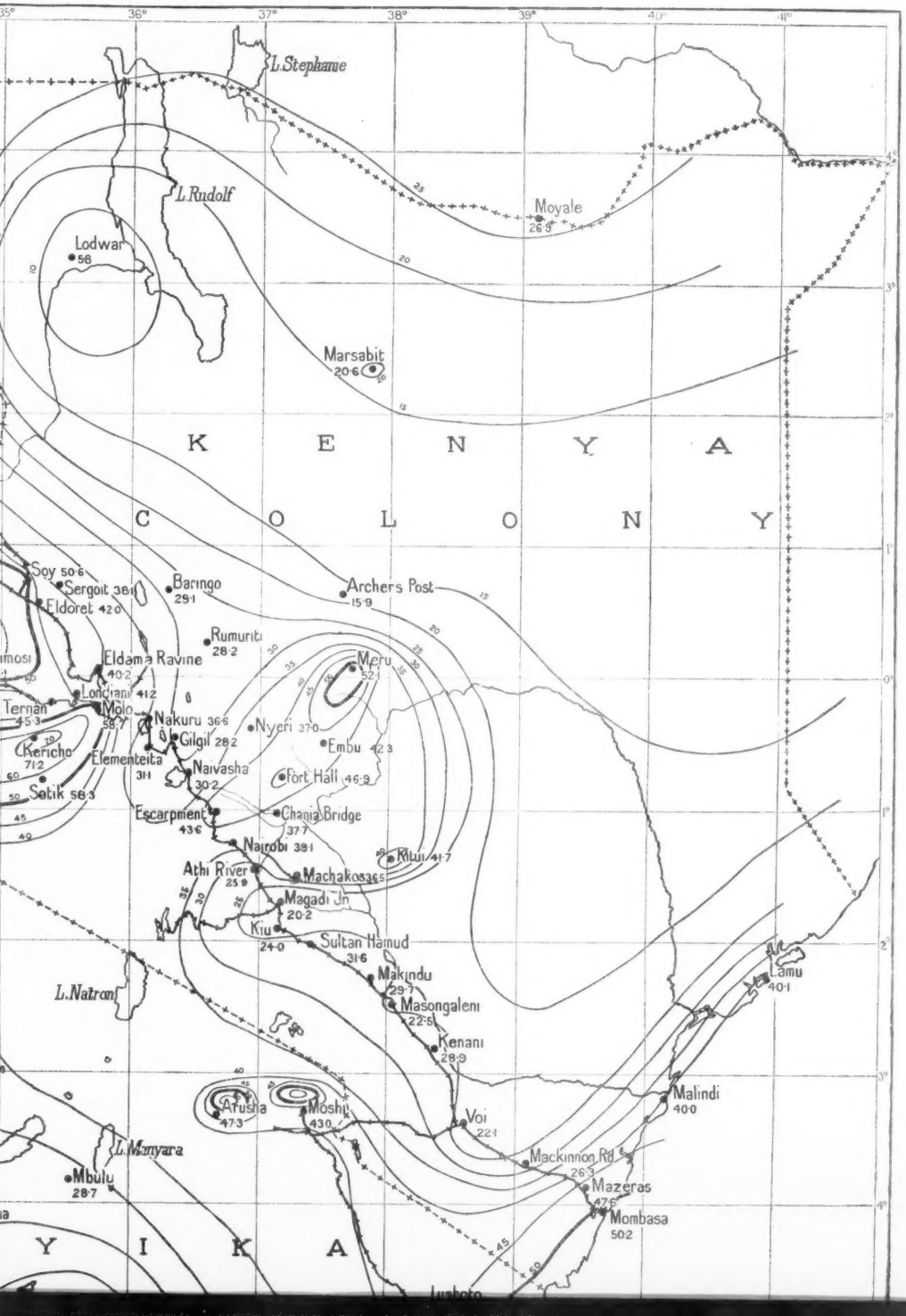
Chart N°2.

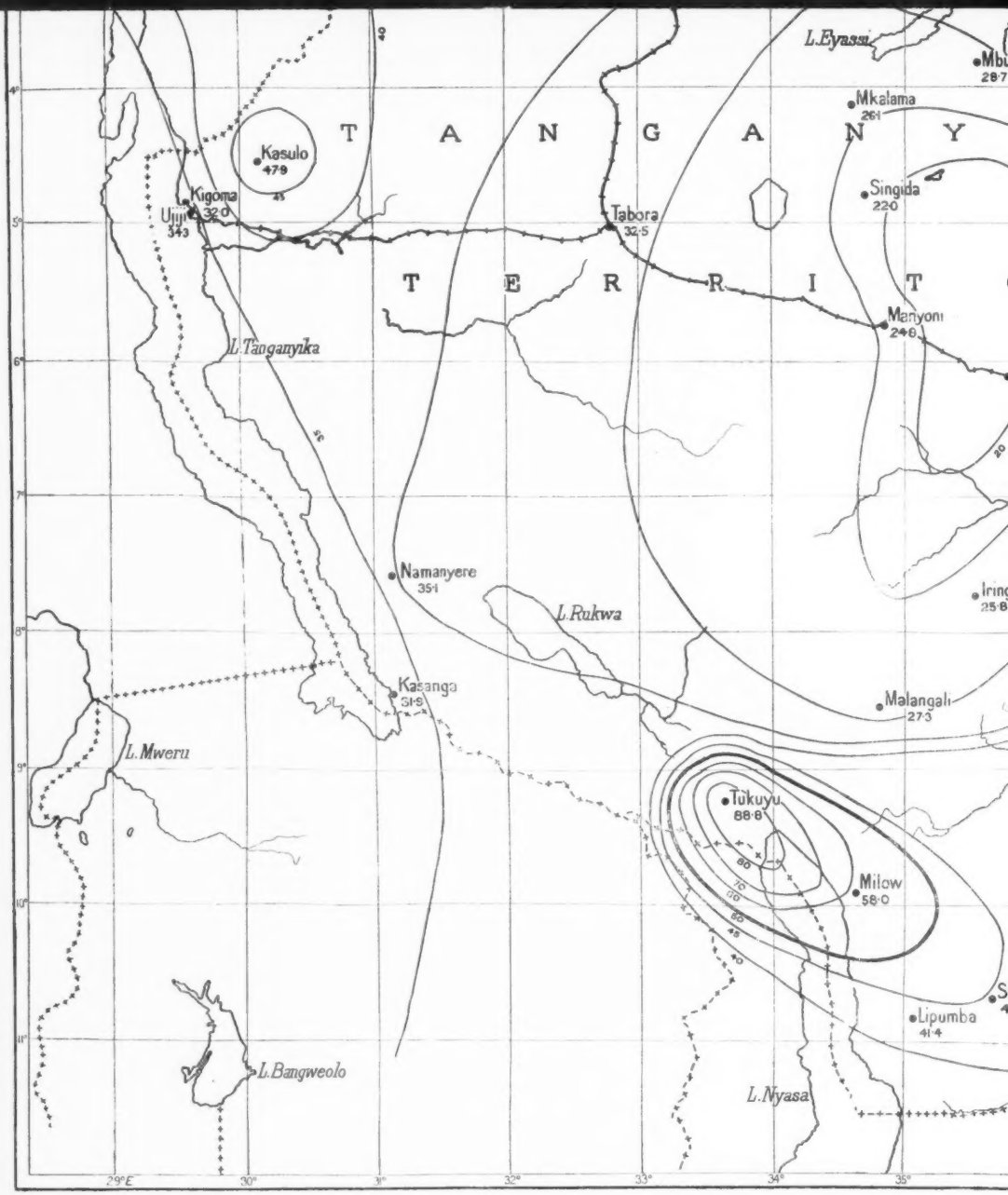
EAST AFRICA, showing isohy



N°2.

g isohyets (in inches).




TANGANYIKA TERRITORY
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Mkalama
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Singida
22·0
Tabora
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Manyoni
24·6
Kasulo
47·9
Kigoma
32·0
Ujiji
34·3
L. Tanganyika
Namanyere
35·1
L. Rukwa
Kasanga
31·9
Malangali
27·3
L. Mweru
Tukuyu
88·8
Milow
58·0
Lipumba
41·4
L. Bangweolo
L. Nyasa
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32°
33°
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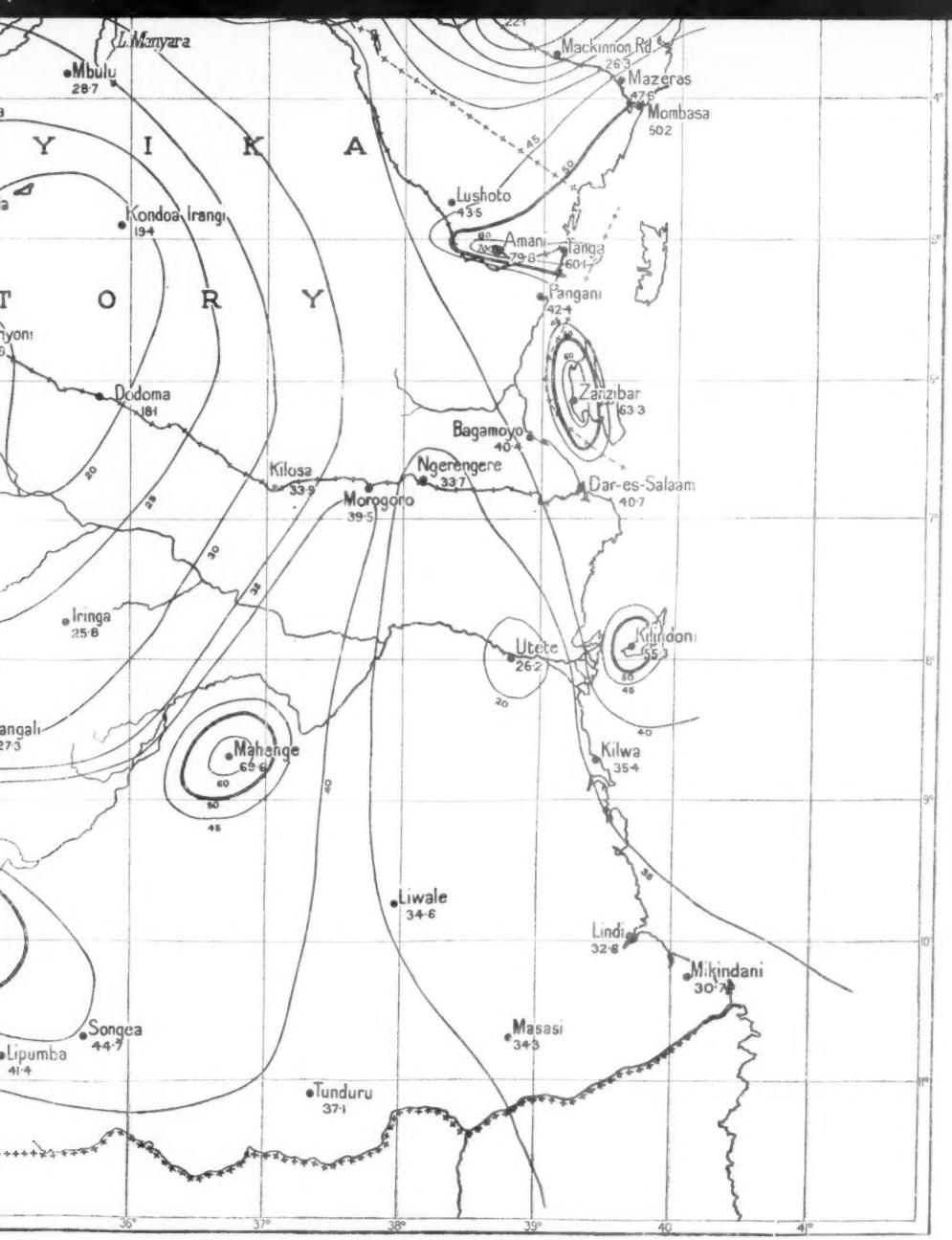

L. Manyara
Mbulu
28·7
Mackinnon Rd.
26·3
Mazeras
47·6
Mombasa
50·2
Y I K A
T O R Y
Kondoa-Irangi
19·4
Lushoto
43·5
Amani
79·8
Tanga
60·1
Pangani
42·4
Dodoma
18·1
Zanzibar
63·3
Bagamoyo
40·4
Kilosa
33·9
Ngerengere
33·7
Morogoro
39·5
Dar-es-Salaam
40·7
Iringa
25·8
Utete
26·2
Kilindoni
55·3
Mahenge
69·6
Kilwa
35·4
Liwale
34·6
Lindi
32·6
Mikindani
30·7
Songea
44·7
Lipumba
41·4
Masasi
34·3
Tunduru
37·1
36°
37°
38°
39°
40
41°

the vegetation is not truly tropical. It is all of the type which will resist the drought of the northern winter months. Even here at 5°N. latitude, one has not reached the divided rains zone, the rainfall of Mongalla reaching an annual total of 39 inches, with a maximum of 5.8 inches in August, the rain season extending from April to October.

The first evidence of a divided rainy season is found at Nimule 3°40′N. on the Uganda Sudan border, at Arua (3°N.) in the West Nile District of Uganda and Gulu (2°45′N.) in the Northern Province, there being at each place a slight diminution in June between maxima in May and July or August. The really dry season in all these places, however, extends only over the months of December to March. From here to Tabora (5°S.) in Tanganyika, with slight variations, the true divided equatorial rain season extends. This belt, it will be noted, includes all the more important areas of East Africa—practically the whole of Uganda; Kenya, including Nairobi and the Highlands and Mombasa, but excluding the Northern Frontier; the whole of Lake Victoria; Tanganyika, as far south as the Central Railway, including the Arusha, Moshi, Tanga and Dar es Salaam areas.

Proceeding south, the southern part of Tanganyika has a single rainy season from December to March or April, with slighter rainfall extending into November and May. The concentration of the rains into the four months December to March as the latitude increases to 11° in the south, is marked.

The seasonal distribution of rainfall in East Africa is shown in the accompanying Chart No. 1.

Southwards, through Rhodesia and Nyassaland, there is a still further concentration of the rains to the (southern) summer months, and at the same time a diminution of the total fall. In the south west, the Kalahari Desert, lying between 20° and 30°S. latitude, provides a counterpart to the desert regions of the corresponding northerly latitude. Within these latitudes, rainfall, while still a summer phenomenon, is plentiful only in the highlands of the east and along the east coast, the rainfall being largely governed by the moist, south-east trades from the Indian Ocean.

In the extreme south, only the small area surrounding Cape Town, and to a less extent a fringe along the coast of the Cape Province, receives winter rains (May/August).

The accompanying rainfall map (Chart No. 2) shows the distribution of rainfall in Kenya, Uganda and Tanganyika. From the map, it will be seen that there is considerable local variation of rainfall. There is a coastal rain belt of some 20 to 40 miles in width south of the equator, *i.e.*, south of the Kenya-Italian Somaliland border. This increases in intensity as one gets further south from the equator, has an annual value of 40 inches at Lamu, 47 inches at Mombasa, reaches a maximum at Tanga with 60 inches a year, decreases to 41 inches at Dar es Salaam and further to 33 inches at Lindi, the effect doubtless of variations in contour along the coast, combined with the increasing strength of the south-east trade wind as one recedes from the equator.

There is a marked arid region (with less than 30 inches of rain annually) lying between the coast and the highlands. This is best visualised as an extension of the almost desert region of Somaliland, north-east of Kenya. It embraces practically the whole of the Northern Frontier Province of Kenya, where the fall is less than 20 inches, and extends in a belt some 200 miles in width between Nairobi and Mombasa. Across the Tanganyika border, this arid belt is not so uniform. It is broken by the rain areas of such mountains as Kilimanjaro, Meru and the Pare and Usambara Ranges, and is traceable to its fullest extent only in the Central Province, *e.g.*, Kondoa Irangi, the Masai Steppe, Dodoma and the arid bush plain lying to the west of the

Dodoma-Iringa road. It will be noted that the arid region here is considerably further inland than in Kenya—in other words, the coastal rain belt of Tanganyika is wider.

It will further be noted that there is a region of excessive rainfall (80 inches) on the slopes of all the high mountains—Kilimanjaro, Meru, Kenya, Elgon, Ruwenzori, and probably Mfumbiro. These figures are, to a certain extent, estimated, and that the rainfall rapidly diminishes away from the slopes of these mountains, may be judged from the rainfall for Moshi, 20 miles from the summit of Kilimanjaro (43 inches), and Arusha at the foot of Mount Meru (47 inches). There is another region of excessive rainfall, approximating 80 inches annually, on the west and north-west shores of Lake Victoria—Bukoba (76 inches), Sesse Islands (81 inches). This area rapidly diminishes in intensity inland, and the excessive rainfall is confined to the shores of the lake. No doubt the passage of the prevailing wind (E. to S.E.) across the 150 mile expanse of Lake Victoria, combined with the usual sea breezes off the lake by day, is responsible for this excessive rainfall without the presence of any high land to assist the process. An interesting sidelight on this climatic feature is the presence of a great deal of the tropical rain forest of Uganda around the western and northern shores of the lake, that which exists to-day only indicating the vast extent of the forest in bygone days.

Two other areas of heavy rainfall should be noted, one of considerable economic importance covering the Highlands of Kenya, and the other, very localised but an extremely interesting example of convection rainfall, at Tukuyu in southern Tanganyika, which is of sufficient importance to affect the main air route to South Africa.

The distribution of rainfall throughout the year and the day is of as much importance to aviation as is the total fall. It is a well known fact that tropical rainfall is extremely concentrated. One is forced to the conclusion, after studying the conditions in East Africa, that the concentration in time and space is such that rainfall as an obstacle to flying is one of secondary importance. The number of non-flying days on account of rain, or non-flying hours on a rain day, in East Africa is much less than the number in the United Kingdom. One set of figures will serve as an illustration. Buganda, on the north-west side of Lake Victoria, has an average annual rainfall of 50 inches, an average of 128 rain days a year and an average fall per rain day of .39 inches. Kew has a mean annual rainfall of 23.8 inches, 167 rain days and an average fall per rain day of .14 inches.

How concentrated, both in time and space, the rain can be, may be judged from the fact that one afternoon in April, 1928, a rain gauge in Nairobi recorded 7 inches of rain. Elsewhere in Nairobi, one was conscious of a heavy fall, but not of a phenomenal fall, and no other rain gauge in the district recorded anything approaching this quantity.

Figures to show how the rainfall is still further concentrated within the day are not available, but certain general observations will show that only a few hours of each rain day are even comparatively unfit for flying.

A fair general rule for African rainfall, which applies particularly in the uniform region of the Southern Sudan, is that the rain falls in the form of afternoon and evening thunderstorms. Mornings are usually clear. The convection set up by the heat of the sun's rays, combined with the naturally great evaporation, induce conditions favourable to thunderstorms with heavy rainfall.

This rule is subject to a good number of local variations. It appears to be a more or less universal rule that during the rainy season mountains induce morning rains. The sequence at Arusha at the foot of Mount Meru and Moshi at the foot of Kilimanjaro is:—Rain sets in at some early morning hour, probably between 3 a.m. and 6 a.m.; heavy rain, with very low cloud covering

all the foothills and outlying spurs, lasts until about 9 o'clock; rain then ceases and clouds gradually lift throughout the day until the peaks themselves become visible in the evening. Mount Meru is approximately 15,000 feet and Kilimanjaro over 19,000 feet in altitude. The same process can be observed round other high mountains such as Kenya, Elgon and Ruwenzori. Even lesser isolated peaks have been observed to produce much the same effect. The highland plateaux of Kenya appear to have the same tendency, but to be insufficiently high to produce regular morning rains. During the rainy season, cloud lying on the higher ridges of the plateaux, such as the Mau Summit and the eastern escarpment of the Rift Valley is a common sight until about 9 a.m., when it lifts. Rain, however, in the absence of definite measurements, appears to occur indifferently during the morning or the afternoon, but with a general tendency for the heavier falls to occur in the afternoon and evening.

A striking example of the reversal of the rule of afternoon rains is found locally on the Entebbe Peninsula (N.W. Lake Victoria). Here with singular regularity, torrential rain is experienced at various times between about 7 a.m. and 11 a.m., and with equal regularity the afternoon is brilliantly clear. How far this condition extends round the shores of the lake is not known, but at Kampala, 25 miles away, near the head of an arm of the lake, the rainfall is much less regular.

Visibility and Cloudiness

Fog and low visibility, as understood in England, is practically unknown in any part of East Africa. Such "fog" as does occur is generally in the form of low cloud on the mountains and high plateaux. For this reason, these two phenomena will be dealt with together.

The commonest cause of low visibility is the torrential rain which occurs all over the territory. During rainstorms the clouds are low, and visibility is sometimes such that flying conditions within the storm would be dangerous. In spite of this, the concentration of the rains, both in time and space, is such that a pilot would not necessarily have any difficulty in avoiding the worst areas. This is particularly true of the afternoon thunderstorms and only less so of the morning rains of the mountain and lake areas. Captain Gladstone, during the experimental service from Khartoum to Kisumu, accumulated a certain amount of experience of this. Generally he was able to avoid the storms, and on occasions he flew through them.

Low cloud around the mountain peaks accompanies the concentrated rains which have already been referred to. Thus, in the early morning during the rainy season, at Arusha (4,400 feet) and Moshi (2,650 feet), in spite of their comparatively low altitude, one may find the cloud system of the neighbouring peaks of Meru and Kilimanjaro so low as to interfere with flying until about 9 o'clock. Similar conditions will be found locally round other high peaks, but the interference with flying on this account is restricted to a small area and the early morning hours of the rainy season. A feature of East African climate, particularly in the highlands, is the occurrence of two or three cloudy months following the long rains in April and May. During the latter part of May, June, July and part of August, while very little rain falls, an overcast sky is a very common feature and may be experienced for days on end. The cloud is usually of the strato-cumulus or cumulus type with other clouds in the higher strata. Generally speaking, this cloud is too high to interfere with flying, but both during the rainy season and the following cloudy season, it will frequently be found resting on the higher ridges of the plateaux on both sides of the Rift Valley during the early hours of the morning. The route from Kisumu to Nairobi, therefore, may be impassable at Mau Summit and Kijabe until about 9 o'clock during some months. There are no definite

observations to assist, but I should estimate that such low cloud occurs on about 50 per cent. of mornings. The Kijabe escarpment would more frequently be passable at a more southerly point than the direct route, that is, due west of Nairobi. The incidence of low cloud at points such as this is one of the questions which the newly-formed East African Meteorological Service may with advantage study in the interests of aviation.

Another area of general cloudiness, which is not restricted to the rainy season, has already been referred to in connection with the main route from East Africa to South Africa. Tukuyu and the country lying within the horse-shoe of mountains at the north end of Lake Nyassa has probably the highest rainfall of any place at a habitable altitude in East Africa. This being due to the formation of cloud by the interference of the mountains with the south-east wind off Lake Nyassa, it follows that the crossing of these mountains is frequently interfered with by cloud. Not only in the rainy season but in the relatively dry months also, cloud on the higher mountains is a daily occurrence, and there is a high but unrecorded frequency of cloud on the lower passes. For this reason it has been recommended that Tukuyu should be eliminated from the main route to the south.

A few records of cloud amounts along the coast show a remarkable uniformity of distribution throughout the year. The same is true of Entebbe, the only station for which observations are available in the Lake Victoria basin. It will be noticed that the total amount of cloud on the coast decreases towards the north. The figures of cloud amounts on the 0 to 10 scale are :—

		Maximum.		Minimum.	
Coastal Stations or Islands:—	Mean/Year.	Month.	Amount.	Month.	Amount.
Lamu, 2° 16′ S.	2.8	May	3.7	September	2.0
Mombasa, 4° 3′ S. ...	4.6	May	5.7	Feb./March	4.0
Zanzibar, 6° 10′ S. ...	6.2	April	6.9	June	5.3
Bagamoyo, 6° 26′ S. ...	4	April	6	Sept.-Oct.	3.0
Lindi, 10° 0′ S.	4.2	January	5.6	June	3.1
Lake Stations:—					
Entebbe, 0° 3′ N... ...	3.6	Mar./June/Aug.	3.8	October	3.4

It should be noted that these are the two regions where the seasonal distribution of rain is most even. Figures for the highlands of Kenya and the inland plateau of Tanganyika as well as the northern part of Uganda would, if available, show a wider variation in cloud amount from month to month.

It remains to add that cumulus cloud is a naturally frequent phenomenon, and that it is also fairly frequent in the dry hot months of January to March (Kenya and Uganda). Remarkable examples of cumulus cloud, formed solely by convection from bush fires, may be seen during this season.

The smoke from grass fires has often been cited as a cause of low visibility which would interfere with flying. While it does interfere with such operations as air photography, there is no evidence that the smoke is ever so dense or widespread as to make ordinary flying difficult.

Grass and sometimes bush is burnt by the natives towards the middle of the dry season, so that cattle may feed on the young growth which springs up after the fire. In Southern Tanganyika, the season is July and August. In Kenya, it is January and February. In some parts of Uganda, *e.g.*, Ankole, grass fires occur in the dry season between the two rains, *i.e.*, July. In the Sudan, large fires occur in the sudd swamps in January and February.

In all cases, burnt and burning particles of grass are carried with the smoke to a height of many thousands of feet.

Thunderstorms

The development of thunderstorms is more or less limited to the rainy season. Thus at Gondokoro (4°54′N.) 11 occur during May and

only 4 from October to March, out of a total of 28 days of thunder in the year. At Entebbe, where there is a total of 41 days of thunder in the year, they are very evenly distributed, and reach a maximum of 5 in April, following more or less the distribution of rainfall. At Tosamaganga, near Iringa, where there are 31 days of thunder in the year, all occur between October and April and 17 in December and January—again coinciding with the rain season. These stations are representative for the different districts.

Wind

From the scanty observations available, only general deductions can be drawn as to the prevailing wind. The coast region is naturally the best known.

The coastal regions of Kenya and Tanganyika are under the influence of two winds :—

(*a*) The S.E. trade from May to October;
(*b*) The N.E. monsoon from November to March.

Neither of these winds is uniformly continued over the continent, but each appears to be deflected at the coast. Thus, in the S.E. trade period, when the zone of these winds extends almost as far north as the equator, the wind appears to be deflected from S.E. to S.W. about the East African coast, and north of the equator, becomes part of the south-west monsoon which blows across the Indian Ocean. During the opposite period, when the south-east trades do not extend beyond 10° south, the N.E. monsoon is deflected at the East African coast and passes down the Mozambique Channel, into which the S.E. trade does not then extend. The extension of the N.E. trade to the south of the equator is a purely local effect along the African coast and is not observed further east in the Indian Ocean.

The S.E. trade, therefore, appears as anything between S.W. and S.E., with a considerable bias towards the S.W. quadrant, and similarly the N.E. monsoon appears as anything between N.W. and N.E.

In the interior, very few precise observations of wind have been made, and all that can be said is that the great majority of winds are from S.E. to E., tending to be more easterly, or even E.N.E., in the northern parts, *e.g.*, Nairobi, and more S.E. in the southern parts (Tanganyika). While meteorologists consider that the trade winds do not penetrate into the interior to any great extent, winds appear to be more variable during the period of the N.E. monsoon.

These interior winds are rarely strong—winds exceeding 30 m.p.h. being very infrequent. An exception, which there are no meteorological observations to support, is found on the Iringa plateau in Tanganyika. Here very strong winds, estimated at 30 to 40 miles an hour, and on occasions more, sweep over the plateau from the E. and S.E., and are exceptionally marked locally where the topography supports them, as at Iringa itself. The area affected extends southwards to Malangali, and somewhat the same effect is observed at Mbeya, in the extreme south of Tanganyika, between the Poroto and Mbeya Mountains. The wind is strongest here in the early hours of the morning and gradually dies away during the day. These winds are said to persist throughout the year, and during the dry, cool season (May to September) they are bitterly cold.

The shores of Lake Victoria and Tanganyika are subject almost entirely to winds of the land and sea breeze type. From such observations as are available, it appears safe to say that, at any lake station, the wind blows off the lake during the day, reaching a maximum in the early afternoon from calms in the morning, and that in the evening a land breeze of much lesser force is experienced. These winds are rarely strong. Hence Entebbe has south winds during the day, Kisumu south-west and Manza north-west.

The northerly winds of the Nile Valley appear to have their southern limit about the north of Uganda, *i.e.*, in 3° or 4°N. latitude, during the winter months November to March, but during the remainder of the year, the S.E. and S.W. winds, mainly the latter, penetrate progressively further north. In July, August and September, S.W. winds are experienced as far north as Atbara (approximately 18°N.)

Very little upper wind data has been secured. From a few observations at Nairobi, Kisumu, Mombasa, Dar es Salaam and Zanzibar, and from his experience as Director of the Observatory at Mauritius, Mr. A. Walter, the head of the new East African Meteorological Service, expresses the view that N.E. and E. upper winds prevail over East Africa.

Captain Gladstone found, on his experimental flights from Khartoum to Kisumu, that the north wind in the Nile Valley frequently changed to south at a height of about 7,000 feet.

Violent dust devils and miniature whirlwinds, which reach a height estimated at over 5,000 feet, are a common occurrence in the hot part of the day during the dry season—January, February and March,—particularly in the Rift Valley. As many as half-a-dozen major ones may be seen at once. One was observed in early February, 1928, which contained practically no dust, but appeared as a thin column of vapour reaching from the ground at 6,000 feet to clouds at the altus level, which indicates a violent circulation of air in the vicinity.

Temperature

From an aeronautical point of view one of the chief points to emphasise is that nowhere in East Africa, or, generally speaking, elsewhere in the equatorial zone, are the high temperatures of a more northerly zone experienced, *e.g.*, as in India, Iraq, Egypt and the Sudan. The mean annual temperature varies round about 70°F. to 80°F. The coastal belt and the regions round the lakes are characterised by slightly higher mean temperatures, very equable conditions, varying little throughout the year, and high humidity, the latter particularly on the coast. While the interior is subject to greater variations both diurnally and annually, the difference is mostly in lower minima. A temperature of 100°F. anywhere in East Africa may be regarded as an exceptional occurrence, except in the dry northern parts of Kenya.

Figures for a few stations will illustrate these points:—

Coastal Zone.

Mombasa (4° 3'S.) Sea Level.	*Temp.*	*Month.*
(1) Mean of daily maximum	83°F.	—
(2) Month of highest mean daily maximum (hottest)	87°F.	March
(3) Mean of daily minimum	73°F.	—
(4) Month of lowest mean daily minimum (coolest)	70°F.	July, August, September
(5) Absolute maximum recorded	93°F.	February, March
(6) Absolute minimum recorded	61°F.	June
Lindi (10° 0'S.) Sea Level.		
(1) Mean of daily maximum	88°F.	—
(2) Month of highest mean daily maximum (hottest)	90°F.	November, December, February
(3) Mean of daily minimum	70°F.	—
(4) Month of lowest mean daily minimum (coolest)	65°F.	June
(5) Absolute maximum recorded	99°F.	December
(6) Absolute minimum recorded	56°F.	June

Lake Victoria Zone.

Entebbe (0° 5′N.) *Altitude 3,750 feet.*

(1) Mean of daily maximum	78°F.	—
(2) Month of highest mean daily maximum (hottest)	80°F.	October, January, February
(3) Mean of daily minimum	63°F.	—
(4) Month of lowest mean daily minimum (coolest)	61°F.	August
(5) Absolute maximum recorded	89°F.	April, October, November
(6) Absolute minimum recorded	52°F.	October, May

Kenya Highlands.

Nairobi (*Kabete* 1° 16′S.) *Altitude 6,000 feet.*

(1) Mean of daily maximum	74°F.	—
(2) Month of highest mean daily maximum (hottest)	78°F.	March
(3) Mean of daily minimum	52°F.	—
(4) Month of lowest mean daily minimum (coolest)	48°F.	August
(5) Absolute maximum recorded	87°F.	March
(6) Absolute minimum recorded	34°F.	July

Tanganyika Inland Plateau.

Tabora (5°S.) *Altitude 3,725 feet.*

(1) Mean of daily maximum	86.4°F.	—
(2) Month of highest mean daily maximum (hottest)	92.1°F.	October
(3) Mean of daily minimum	62.5°F.	—
(4) Month of lowest mean daily minimum (coolest)	58.3°F.	June
(5) *Mean of yearly absolute maxima* ...	94.3°F.	—
(6) *Mean of yearly absolute minima*	51.3°F.	—

Humidity

Relative humidity varies from the extremely moist conditions of the coast and lake regions to the dry arid conditions of the northern parts of Kenya.

The period of maximum relative humidity in all districts occurs in the morning up to about 0900 hours, and reaches a maximum for the year in the wet season. The mean relative humidity at 0900 on the coast is fairly constant in the region of 80 per cent. throughout the year, *e.g.*, Lamu 76 to 81 per cent., Mombasa 73 to 82 per cent., Zanzibar 79 to 87 per cent., Lindi 72 to 85 per cent. The driest period of the day is in the afternoon. Extreme figures of 36 per cent. at Tanga, 35 per cent. at Dar es Salaam, and 33 per cent. at Lindi have been recorded.

On the inland plateau of Tanganyika, represented by Tabora, Kondoa Irangi and Iringa, figures of approximately 90 per cent. are reached in the morning during the wet season and about 65 per cent. in the afternoon. During the dry season the morning figures are down to 60 per cent., and the afternoon figures to 40 per cent. Extremes of 9 and 10 per cent. have been recorded.

Taking Entebbe, Mwanza and Bukoba as representative of the Lake Victoria region, the mean relative humidity at Entebbe varies only from 78 to 81 per

cent. throughout the year; Mwanza and Bukoba reach a maximum of 90 per cent. approximately at 0700 in the wet season (April), and a minimum of 48 and 59 per cent. in July.

Pressure

Mombasa may be taken as representing fairly the coast district. Mean pressure for the year at 0900 is 1,013 millibars, a minimum of 1,011 mb. being reached in February, March and April, and a maximum of 1,016 mb. in July, August and September.

At Entebbe, at an altitude of 3,750 feet on Lake Victoria, the mean for the year is 884 mb., and the variation from month to month is no more than 2 mb.—883 from January to April and 885 from June to August.

It may be taken that the variations of pressure throughout East Africa are small. The region generally lies within the equatorial low pressure belt.

While figures are not readily available to calculate the relative density of the air at a number of stations, one station may be given as an example. At Nairobi, it has been calculated that the minimum relative density of the air is .75 approximately. Nairobi lies at an altitude of 5,500 feet. For other stations, a sufficiently accurate result may be obtained from the figures of barometric pressure at sea level and temperature given above, and the altitude of the station.*

The Cairo—Cape Town Air Service

The Route

Undoubtedly the most important aviation development in prospect for East Africa arises from the fact that the British route to South Africa must pass through, not one, but all three of the territories we are dealing with. A glance at the map of Africa is sufficient to show that the valley of the Nile, if not the only feasible route to Central Africa, is without doubt the most practicable. Neither the east coast nor the west coast offers anything like the same advantages in the way of settlement or ground communications to facilitate the establishment of the air way, and for the rest the Sahara stretches its arid, uncharted wastes as a barrier—though not insuperable—from the western to the eastern limits of the continent.

The flights of the Royal Air Force, Sir Alan Cobham and Captain Gladstone have been the chief instruments in consolidating the knowledge of the route first flown by Sir Pierre Van Ryneveld and Sir Christopher Brand in 1920. As a result of these flights and recent investigations, it has been decided to modify the civil air route from Lake Victoria to Northern Rhodesia; from Kisumu on Lake Victoria, it will pass over more settled regions via Nairobi, Arusha, Dodoma and Mbeya, rejoining the original route at N'dola in Northern Rhodesia, thus eliminating Tabora and Abercorn and the sparsely populated bush region lying between. From N'dola south, the route will practically follow the Cape railway.

It will be noted that the chief centres of commerce in Central Africa lie along the coast—Mombasa, Tanga, Dar es Salaam, etc.; the chief centres of

* The data used in this section has been drawn from the reports published by the Departments of Agriculture of the three territories, Kenya, Uganda and Tanganyika and from the following papers, "The Distribution of Rainfall over Uganda," C. E. P. Brooks, Quarterly Journal of the Royal Meteorological Society, October, 1924; "Climatological Studies: German East Africa," H. G. Lyons, Quarterly Journal of the Royal Meteorological Society, April, 1917; and a summary of the climatic conditions for aeronautical purposes produced by Captain F. Entwistle of the Meteorological Office. I have to thank Captain Entwistle for his advice on this section.

industry lie outside British territory, in the north-east and south of the Belgian Congo—Kilo-Moto mines and Katanga mines; while the line chosen for the through route links the chief centres of settlement—Kenya Highlands, Arusha, Iringa Highlands, and the Fife district.

Some parts of the route are suited to the operation of seaplanes, others to the operation of landplanes. From Cairo to Khartoum the terrain is desert, and the Nile is an uncertain river winding between sandbanks. Landing grounds are easily prepared and easily maintained, safe forced landing grounds are abundant, and generally the operation of aeroplanes presents less difficulty than the operation of seaplanes.

From Khartoum to the southern border of the Sudan the region of tropical rains having been entered, the soil is either black cotton soil or swamp, the making of all weather landing grounds is either difficult or impossible, and the Nile and lakes provide admirable alighting places for seaplanes. From Khartoum to the lakes of Central Africa, therefore, the route is only feasible as a seaplane route. Detours either to the west or east, to avoid the impossible area of the sudd, involve flight over partially isolated or even unknown regions where the problem of supplies would at present be insurmountable.

South of Lake Victoria while both Mittelholzer and Sir Alan Cobham have completed the flight by seaplane to the coast of Portuguese East Africa, the difficulty of making and maintaining landing grounds is not great, and there are long stretches of land between suitable alighting places for seaplanes. From Kisumu to Cape Town, therefore, is a land machine route. Kisumu, under this arrangement, becomes an important change-over station, and it is fortunately ideally suited for this purpose, having a landing ground in close proximity to the lake.

Following the support given to Captain Gladstone for his experimental service from Khartoum to Kisumu, the three East African Governments and the Sudan decided in 1928 to support with subsidy a permanent service. In the debate on the Air Estimates in March the Secretary of State for Air announced that it had been decided to proceed with the development of the African service. It goes without saying that it will not be possible to develop the whole route at one time, and the first section to receive attention will be that from Egypt to East Africa. In order to provide a connection to Tanganyika, it is contemplated that the service should be extended to Mwanza, the terminus of the newly opened branch line from Tabora. When the southern section of the line via Dodoma is opened, this extension from Kisumu will become of less importance, and may be abandoned.

Traffic

The following tables and data give an idea of the amount of traffic on which the air service in this section may draw. The figures represent approximate averages. Mails are given separately for each country.

Mail Traffic.

Sudan.	*Letters.*	*Newspapers.*
Inward mail from London per week	840 lbs.	9,000 lbs.
Outward mail to London per week	700 lbs.	—
Inward mail from Egypt per week	4,900 lbs. (includes newspapers).	
Outward mail to Egypt per week	2,400 lbs.	
Transit mail to Belgian Congo (via Rejaf) ...	70 lbs.	2,300 lbs.
Transit mail from Belgian Congo (via Rejaf) ...	70 lbs.	—

Despatches (via Cairo) to and from Khartoum, bi-weekly in the winter, weekly in the summer.

Kenya and Uganda.	*Letters.*	*Parcels.*
Inward mail from London per week	650 lbs.	22,000 lbs.
Outward mail to London per week	650 lbs.	1,500 lbs.
Inward mail from India per week	550 lbs.	370 lbs.
Outward mail to India per week	550 lbs.	370 lbs.

Despatches of mail are irregular; there is no regular mail boat service to East Africa. The average interval between London mails is 5 days, but this sometimes extends to 12 days. The average time of transit is 19½ days. To India, the average time of transit is 9½ days, and the average interval 11 days.

Tanganyika.

Weekly weight of mail in each direction (London)	200 lbs.
Weekly weight of mail in each direction (India)	120 lbs.
Weekly weight of mail in each direction (Congo transit) ...	140 lbs.

As in the case of Kenya, there is no regular mail. There is an average of 4 mails a month to and from Great Britain and 2 to India. The interval between mails extends sometimes to 18 days and 14 days respectively. The average time of transit is 22 days to London and 12 to Bombay.

Passenger statistics are given in the following table. Owing to the difficulty in collecting statistics these figures are only roughly correct.

Passenger Traffic.

Between	*First class passengers annually.*
Cairo and Khartoum	3,500
Khartoum southwards by Nile steamers	1,200
Khartoum and Europe via Port Sudan	No figures
Mombasa and Europe	10,250 (includes 2nd class)
Mombasa up-country	6,000
Dar es Salaam and Europe	2,500
Belgian Congo and Europe via D.S.M.	1,200

Figures represent traffic in both directions.

There is very little freight of such a nature as will bear the cost of air transport to and from the Sudan or East Africa. Occasionally there may be a demand for the transmission of samples of agricultural produce to the London market, and a certain amount of the parcel post, which is naturally heaviest to Kenya, may be attracted to the air route, either as air mail or freight. The most promising source of freight, however, appears to be the gold from the Kilo-Moto mines in the north-east of the Belgian Congo, and as the mineral resources of the Sudan, Uganda and Tanganyika, which are being actively exploited, develop, this carrying trade may become of some importance. The carriage of specie between Egypt and the Sudan also offers an opportunity for the saving of both time and money.

As is to be expected, with an air service through territory whose communications are only partially developed, considerable time savings will be effected by the use of the air service. The following table shows the savings expected between London and various places as far south as Cape Town, on the assumption that the air service is used right through to London.

CAPE-CAIRO AIR ROUTE.

Time Saving from London.

Place.	Present Route. Method.	Time.	Air Service. Time.	Saving.
	Via Lloyd Triestino Route to Alexandria, and thence by			
Egypt.		Days.	Days.	Days.
Assouan ...	Rail, weekly	5¾	4¼	1½
Sudan.				
Wadi Halfa ...	Rail and Nile Steamer, bi-weekly ...	9	4½	4½
Atbara ...	Rail and Nile Steamer, bi-weekly ...	9¾	5¼	4½
Port Sudan ...	Rail and Nile Steamer, bi-weekly ...	11	6¾	4¼
Khartoum ...	Rail and Nile Steamer, bi-weekly ...	10	5½	4½
Malakal ...	Rail and Nile Steamer, bi-weekly ...	14	6¼	7¾
Mongalla ...	Rail and Nile Steamer, bi-weekly ...	21	6½	14½
	Via Overland Route to Marseilles; P. & O. Steamer to Port Said, and thence by			
Uganda.				
Entebbe ...	Rail and Sea, via Suez, irregular ...	21	7½	13½
Kenya.				
Nairobi ...	Rail and Sea, via Suez, irregular ...	20	7½	12½
Mombasa ...	Sea, via Suez, irregular	19	8	11
Tanganyika.				
Dar es Salaam ...	Sea, via Suez, irregular	21	9½	11½
Tabora ...	Rail and Sea, via Suez, irregular ...	22½	9	13½
	Via Sea to Cape Town and thence by			
Northern Rhodesia.				
Broken Hill ...	Rail, weekly ...	21	10	11
Southern Rhodesia.				
Salisbury ...	Rail, weekly ...	21	12	9
Bulawayo ...	Rail, weekly ...	20	11	9
Union of S. Africa.				
Johannesburg ...	Rail, weekly ...	18-19	11½	6½-7½
Durban ...	Rail, weekly ...	19-20	12	7-8
Cape Town ...	Rail, weekly ...	17	12½	4½

It will be seen that there is a considerable volume of traffic to be dealt with and that the time savings are considerable. The prospects for the service, therefore, while not as good as on such a route as the Indian route, are not unfavourable commercially. The completion of its development through to South Africa will have the important political result of linking up the two important areas of white settlement, East Africa and South Africa, which are now separated by great distances, and practically non-existent overland communications.

Other Air Services

Boma to Elizabethville

Without doubt one of the richest territories in Africa, the Belgian Congo, cannot fail to be an important factor in the development of air communications in Africa. To the Belgians, in fact, must be given the credit of having first introduced regular air transport into tropical Africa in 1925, and of still holding the field alone with their service from Boma to Elizabethville. How important this service is can only be realised by those who have appreciated the enormous mineral wealth of the Katanga region.

Connection with the Cape Route

It is inevitable that the aerial activities of the Belgian Congo must be co-ordinated with British development in East Africa. While the Belgian authorities have, after investigating the Nile and other routes, decided to establish, in co-operation with the French, a trans-Saharan air route, connecting with the existing air line at Bandundu, they are also considering a connection with the British route at Juba in the southern Sudan or Butiaba in Uganda. Two possible routes are then open—(*a*) via Stanleyville to Boma and thence by the existing line to Elizabethville; (*b*) down the eastern side of the Congo connecting with the new Belgian provinces of Ruanda and Urundi, parts of which are being developed as white settlement areas.

It is a legitimate Belgian ambition to direct some of the traffic from the Union of South Africa and Rhodesia to their main trunk air line, and they will seek to extend their line from Elizabethville in the south to N'dola, to connect with the British line there. In the meantime their plans involve an extension from Elizabethville, in conjunction with the Portuguese, to Mozambique, and thence, with the French, to Madagascar.

Belgium to the Congo

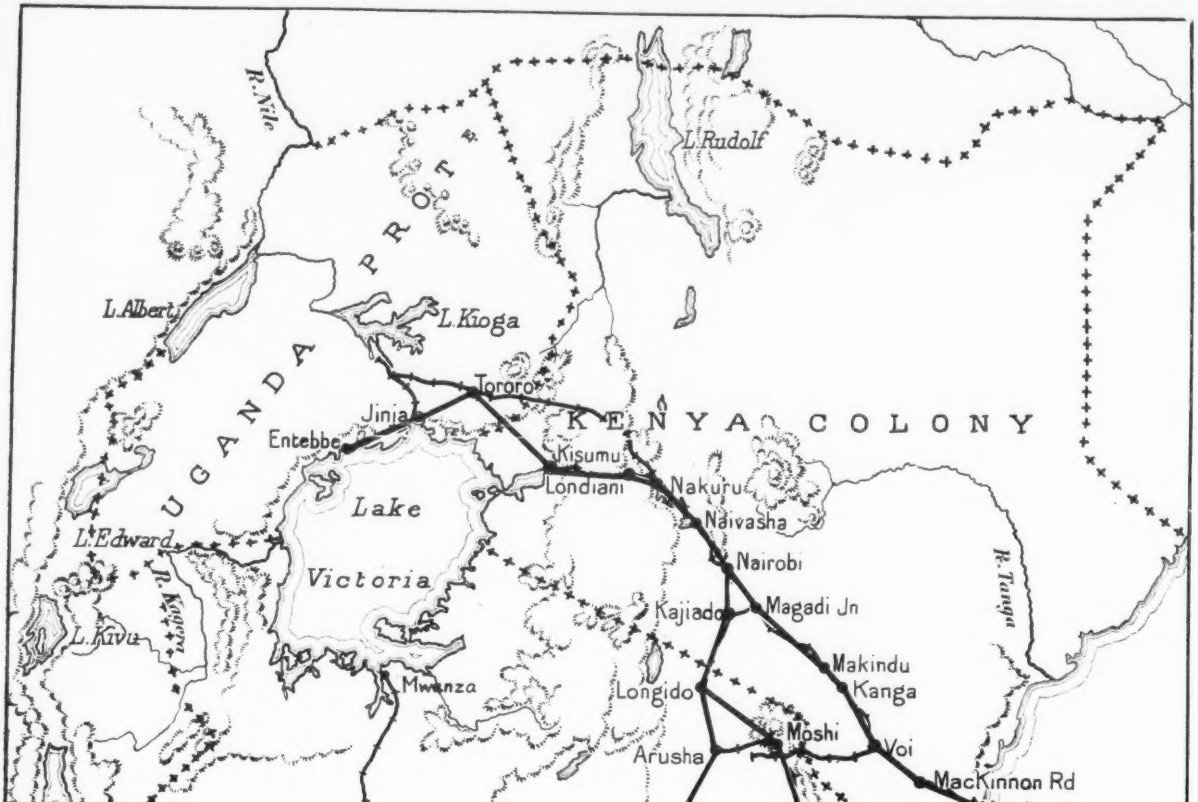
Within the next few years, then, there will be two routes to South Africa, a Saharan and a Nile route, the former also giving access at two points to British Central African territory—in the southern Sudan or Uganda and in Northern Rhodesia. In passing, it may be noted that the Belgian-French trans-Saharan route will be well placed to provide a connection with Nigeria, which, however, may also be served by an extension of the French coastal route from Dakar.

Livingstone to Lobito Bay

An interesting probability is a route from Livingstone along the Zambezi valley and through Portuguese West Africa to Lobito Bay. The new service to be provided by the Union Castle Steamship Co. to this port will enable a considerable saving of time to be effected in passages from South Africa.

Internal Air Routes

There does not appear at the moment to be a prospect of success for a regular commercial air service internally in East Africa, but the increasing demands for mobility on the part of the white settlers and business men, coupled with the possibility of assisting administration and the desirability of effecting closer union between the three territories, by speeding up their communications, points inevitably to the necessity of preparing and maintaining certain key air routes, and does hold out a prospect of success for a "taxi" organisation. Important factors are the lack of railway connections in a north-south direction, though there are three lines of lateral rail communication (already referred to), the slow average speed of rail travel (15 m.p.h.), and the dearth of roads, par-


R. Nile
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UGANDA PROT.
L. Albert
L. Kioga
Tororo
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KENYA COLONY
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Naivasha
Lake
Victoria
L. Edward
Nairobi
R. Kagera
R. Tsavo
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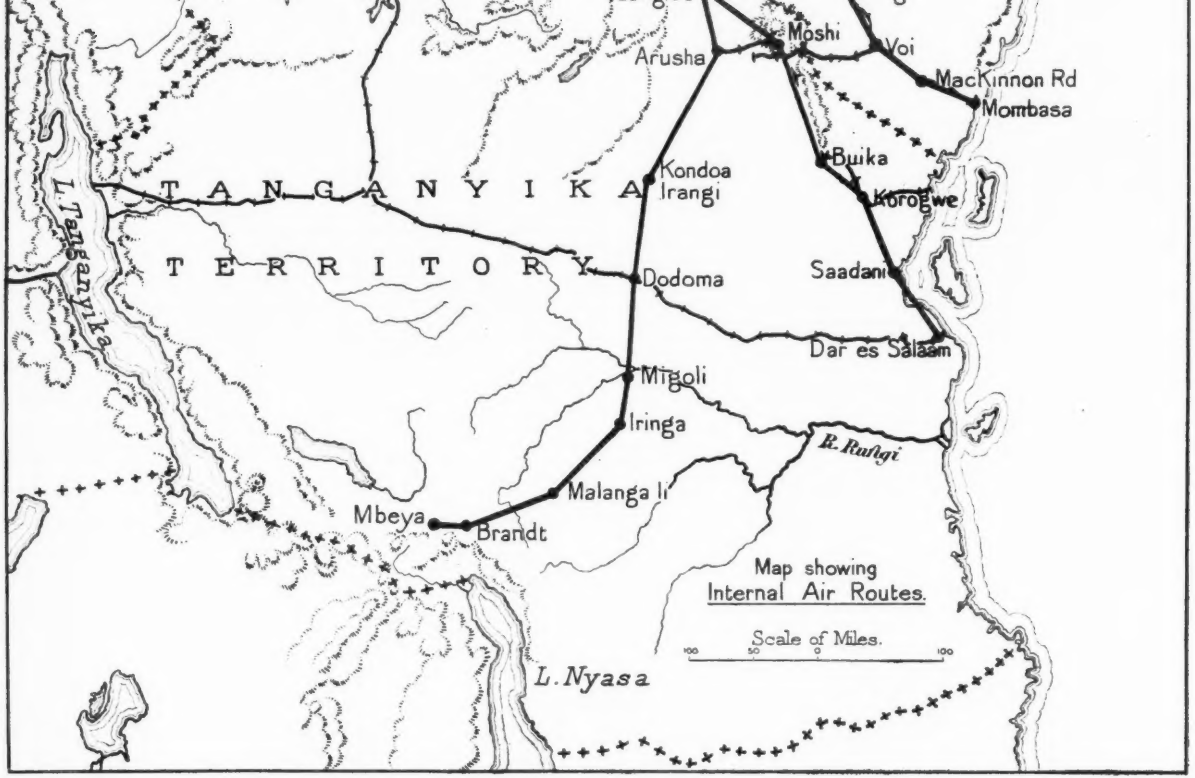
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Dodoma
Saadani
Dar es Salaam
Migoli
Iringa
R. Rufiji
Malanga li
Mbeya
Brandt
Map showing
Internal Air Routes.
Scale of Miles.
100 50 0 100
L. Nyasa

ticularly again in a north-south direction, while most of the roads, except in Uganda, become impassable for several months at a time during the rains.

Main Routes

The three routes which appeared to call for early development are :—

(1) Entebbe, via Jinja, Kisumu and Nairobi, to Mombasa. This broadly follows the Kenya-Uganda railway.

(2) Nairobi to Dar es Salaam, via Moshi.

(3) Nairobi to the southern highlands of Tanganyika, via Arusha, Dodoma, Iringa and Mbeya.

This, it will be observed, is a section of the main civil air route to the Cape.

The administrations of all three territories have adopted programmes which will eventally result in the establishment of landing grounds approximately every 50 miles along these three routes, while in Kenya, through the activities of the Aero Club of East Africa, a start has already been made with the provision of landing grounds at other centres of settlement in the highlands, which will make it possible to reach most important places in the Colony by air from Nairobi. Most of the landing ground sites along the three main routes have been selected.

(1) *Entebbe to Mombasa* (660 miles).

Landing grounds have either been prepared or sites have been selected at :—

ENTEBBE.—Administrative capital of Uganda; 25 miles from the commercial capital Kampala; site now partially prepared.

JINJA.—An original Cape route landing ground; present railhead of the Kenya-Uganda railway; source of the Nile-Ripon Falls.

TORORO.—An important junction station on the K.U.R.

KISUMU.—An original Cape route landing ground; to be developed into a combined aerodrome and seaplane station for the service to South Africa.

LONDIANI.—An emergency landing ground at 7,500 feet on the Mau Plateau.

NAKURU, NAIVASHA.—Centres of white settlement, the former a thriving township, in the Rift Valley.

NAIROBI.—Capital of Kenya and the centre of white civilisation in East Africa; new aerodrome now prepared.

MAGADI JUNCTION, MAKINDU, KANGA, VOI, MACKINNON ROAD.—Stations on the K.U.R. Voi alone is of any importance, as the junction for connection to the Tanga railway at Moshi. Important sisal estates are situated here.

MOMBASA.—The port for Kenya and Uganda, and a rapidly growing town; a landing ground has been selected, which may ultimately be developed into a combined airship station and aerodrome; a seaplane station site has been selected nearby.

The journey from Entebbe to Mombasa takes about 2½ days, and could be done in 7 or 8 hours by air. Trains now run twice a week to and from Jinja. This route could be used, with a slight extension, for flights to the Kilo-Moto area of the Congo, which would show a saving of 4 or 5 days over the boat and train journey. A few Belgian passengers travel via Mombasa and Butiaba.

(2) *Nairobi to Dar es Salaam* (439 miles).

Landing ground sites have been selected along a part of this route. The most important are :—

KAJIADO.—Station on the Magadi railway; administrative centre for the Masai district.

LONGIDO.—Frontier station in the north of Tanganyika.

MOSHI.—Important white settlement centre at the foot of Mt. Kilimanjaro.

Thence the route will follow the Tanga railway to Korogwe, thence via Saadani, on the coast, to Dar es Salaam.

This route joins obliquely the three main railway lines of East Africa. Via Mombasa, it takes 3 days to get from Nairobi to Dar es Salaam, the sea journey occupying 2 days; via Kisumu, Lake Victoria steamers, Mwanza and Tabora by train, it takes 5 days; at times it is possible to motor from Nairobi to Dodoma on the Tanganyika Central Railway and complete the journey in 3 or 4 days.

(3) *Nairobi to Mbeya* (634 miles).

The main landing ground sites are :—

ARUSHA.—Important administrative and white settlement centre at the foot of Mt. Meru.

DODOMA.—Station on the Tanganyika Central Railway and administrative centre.

IRINGA.—A very important and developing white settlement district; large native town and administrative centre.

MBEYA.—A new administrative station and customs post on the main road to Rhodesia.

Other landing grounds have been selected as emergency landing grounds mostly in bush country. This route follows the main north-south road to Rhodesia. Its use will be chiefly as an alternative route to South Africa, and to facilitate inter-communication between the settlement centres of Tanganyika and Kenya.

Throughout the Report of the Closer Union Commission it is stressed that quicker and better communications are needed to facilitate that so much desired and so much abhorred, yet inevitable, closer union. With regard to Nyasaland and Northern Rhodesia, in fact, the conclusion is drawn that the entire lack of communications between them and their northern neighbours is the chief obstacle to any form of political union or co-operation at the present time. It is not inappropriate, therefore, that at this time of political development in East Africa, aviation should step on to the stage and play its part.

In this connection it is of interest to note that the Associated Chambers of Commerce of East Africa, in August, 1928, passed the following resolution :—

> Civil Aviation : " That this Association desires to call the attention of the Governments of Kenya, Uganda and Tanganyika to the urgent necessity of making provision for the establishment of inter-communication by air transport between the three territories, in addition to the Imperial Airway routes, and recommends that :—
>
> (*a*) Land shall be reserved in the town planning of every township for an aerodrome and landing ground; (*b*) Suitable landing grounds shall be developed at intervals along all routes which can produce traffic; (*c*) Every encouragement shall be given to any company or companies of approved repute which may develop an air transport service in the territories; (*d*) Investigation should be made to ascertain how far the Governments can support air transport service by using aircraft for urgent official journeys and for the carrying of despatches and public mails."

Topography of the Internal Routes

Before proceeding to the present and probable future aviation activities in the country, a pen picture of the topography of these three air routes in amplification of the topographical notes given earlier will be of value as a key to the conditions to be dealt with.

The *Entebbe-Mombasa* route starts in the peculiar Buganda country, than which there is nothing more unfavourable to aviation. Over an area extending almost 100 miles in all directions from Entebbe, the Archæan rocks have been weathered down from the original peneplain, forming a succession of hills and valleys of almost uniform height (300 to 500 feet), with an abundance of fertile soil. A vast tropical forest once covered this area, and much isolated forest still remains. The valleys are, without exception, choked by papyrus swamp. For the rest, the fertile soil has attracted a dense population (the Waganda) and led to dense cultivation—bananas and sweet potatoes. All which is not forest, bananas, or papyrus swamp is covered with a rank growth of elephant grass, reaching anything from 12 to 15 feet in height.

After much labour, only one landing ground site could be found in the whole of this area—Entebbe. Jinja already existed, but is a very indifferent landing ground on account of the contour of the ground.

From Tororo to Kisumu the country is of a very much more open type, with light bush and some open grass plains. The altitude lies between 3,700 and 4,500 feet. From Kisumu to Nairobi one passes over the white settled area. East of Kisumu one crosses the Mau Plateau at 8,300 feet. The plateau itself carries a good deal of forest, but there are many short-grass plains and grass glades in the forest suitable for landings. During and after the long rains (May, June and July), clouds often rest on the top of the plateau in the early morning, but invariably clear later in the day.

East of the Mau Summit the ground falls away rapidly to the Rift Valley (Nakuru and Naivasha) at 5,000 to 6,000 feet. The Rift Valley and much of the surrounding country, east and west, is volcanic, and therefore often rough; the floor of the valley is in places covered with bush of a very open type, but is generally grass, and provides an abundance of good natural landing grounds.

The eastern escarpment of the Rift Valley (Kijabe) attains an elevation of 7,500 feet, and, from its summit, it drops away over a series of very rough ridges and closely settled country to Nairobi at 5,500 feet. Below Nairobi, to the east and south for many miles, stretch the Athi Plains (Game Reserve) grass covered and slightly undulating, providing natural landing grounds everywhere, except during the rains, when care has to be taken to select the tops of the ridges to avoid the worst of the black cotton soil, which makes the plains impassable by car.

East of the plains, and stretching from Magadi Junction to within 15 or 20 miles of Mombasa, is the dry arid bush region inhabited, for the most part, by neither native nor white man. Sections of this consist of rocky volcanic hills and boulders, but the selection of sites of unlimited level dimensions, and requiring only the clearing of dry bush to make perfect landing grounds, presented no difficulty. The elevation falls gradually from Nairobi to Mombasa, where the final drop of 700 feet is over a steep ridge running parallel to and a few miles from the coast.

The *Nairobi-Dar es Salaam* route starts over the Athi Plains, crosses some hilly, savannah country in the south of Kenya, and emerges on to other grass plains to the north-west of Kilimanjaro. It crosses the low saddle (3,000 feet) between Mt. Kilimanjaro (19,720 feet) and Mt. Meru (14,950 feet) to Moshi, which lies at the southern base of Kilimanjaro. This part of the route is an alternation of open bush and grass plains. Practically the whole of the route

from Nairobi to Moshi lies over the Masai native reserve. The Masai, at one time a warlike race of cattle herders, now have the former part of their energies restricted to lion hunting.

A meteorological feature of some importance, which is equally shared by Arusha on the main north-south route, is that local rain and low cloud are induced in the early morning by the two mountains, and these clouds, apart from the heavy nature of the rain, may prevent flying over the surrounding ridges and spurs down to about 3,000 feet, until the middle hours of the morning.

From Moshi to Dar es Salaam the route has not been fully explored. It follows the Tanga railway to the neighbourhood of Korogwe, the first part of this section lying over dense bush, of which most of those who took part in the East African campaign will have painful memories. Flanking the route on the north-east side of the railway are the Pare and Usambara Mountains rising to a height of 7,000 feet, the general level of the country dropping from 2,500 feet to 1,000 feet. In the latter half there are many important sisal plantations and derelict rubber plantations started by the Germans. In most parts one may find open grass flats, locally known as mbugas (Rhodesian-dambo), which in the dry weather provide good landing places, but which during the rains are swamps.

Leaving the railway at Korogwe, the route again lies over rather desolate bush country, and emerges on to the coastal fringe of palm trees and cultivation at Saadani. A suitable aerodrome site has been selected at Dar es Salaam, and has already been partly prepared.

The *Nairobi-Mbeya* route branches from the Dar es Salaam route at Longido, which, until there is a full customs union between Tanganyika and Kenya, may be an examination station. Thence it passes over bush plains and open grass plains and downs on the north-western and western flank of Mt. Meru, to Arusha on the south-west flank. Arusha is an important and growing centre of white settlement (coffee growing), and incidentally with its flowers, crystal streams and forest trees, backed by the magnificent mass of Mt. Meru, may claim to be one of the most attractive spots in East Africa.

South of Arusha, which will shortly be the terminus of the Tanga railway, now running only to Moshi, lies a purely native region (Masai), consisting of grass plains and bush plains interspersed with mbugas, and flanked on the west by sundry escarpments and isolated peaks reaching 10,000 feet and forming the eastern wall of the Rift Valley. The route itself does not normally exceed a height of 4,500 feet, and drops to 3,700 feet at Dodoma on the Central Railway, the last 40 miles of this section being fairly thick bush.

South of Dodoma the route first passes over rather broken country, but later emerges on to the great bush plain lying at an altitude of about 3,500 feet to the west of the Iringa Plateau. Through this bush plain runs the Great Ruaha River, having its origin in the Poroto Mountains at the head of Lake Nyassa and flowing in a northerly then north-easterly direction round the northern end of the Iringa Plateau. The whole of this plain is comprised within the arid region referred to as an extension from the Northern Frontier Province of Kenya, and the dry region lying between Nairobi and the coast. It is, in consequence, very sparsely populated, and entirely devoid of white settlement. The hard, sandy nature of the plain and its dry thorn bush covering is such as to make it easy in most places to prepare landing grounds at low cost, except for the dearth of local labour.

The route might reach Mbeya entirely over this plain without crossing the Iringa Plateau, which has a general elevation of 5,000 to 6,000 feet, with isolated peaks of 8,000 feet in its northern part. To do so, however, would mean constructing landing grounds in country entirely devoid of communications, since the main road climbs on to the plateau north of Iringa and follows it throughout its whole length; the route would thereby also miss the whole of

this developing region. The top of the plateau, whose characteristic natural vegetation is myombo forest, is considerably more difficult from the point of view of the construction of landing grounds than the plain. Where grass occurs in the south part of the plateau, a disconcerting feature in a forced landing is the universal presence of a small type of ant heap at close intervals, not more than 9 inches high and entirely invisible when the grass, which is not long for African grass, is standing.

The white settlement area does not start until about 30 miles south of Iringa, and it is developing mainly in a southerly and south-easterly direction. It is still, however, in a very primitive state of development.

Between the southern flank of the Iringa Plateau and the Poroto Mountains, which, with the Livingstone Mountains and the Bundali Hills, surround the northern end of Lake Nyassa, lie the notorious Buhora Flats, an extensive region which becomes an impassable swampy lake in the rains, for some 4 to 6 months in the year, and thereby cuts off Tukuyu and the settlement areas in the south, with Rhodesia, from the rest of Tanganyika. A new road is now being constructed round the flats.

Mbeya itself lies in a wide grass covered valley between the Poroto Mountains on the south and the Mbeya Mountains on the north, both rising to 10,000 feet—5,000 feet above the valley. After crossing the Buhora Flats and climbing the pass to the valley 1,500 feet above, the impression is that of a gateway to Rhodesia and the lands beyond—a rather striking natural feature. The floor of the valley is in many places a natural landing ground, requiring only the burning of the long, wheat-like grass as preparation. A very fine site for a landing ground was found near the Boma, and this, as the customs aerodrome in the south of Tanganyika and a possible night halt on the main route to the Cape, is likely to become of some importance. A further point of interest about Mbeya is that it is the jumping-off point of the mountain track to the Lupa goldfields to the north. These at present are limited to small scale placer mining, but, with the discovery of a reef, the area is attracting the attention of the South African mining groups, and may become of considerable importance.

With these three main air routes prepared, and a few additional landing grounds at other centres of settlement in the Kenya Highlands, such, for example, as Eldoret, Kitale and Nyeri, it will be possible to travel by air between all the important centres in East Africa.

Other Internal Routes

It only remains to mention certain other possible routes of the future. With the exception of one, they all have the Belgian Congo as their objective. The exception is a seaplane route along the coast, connecting Mombasa, Tanga and Dar es Salaam, with probably an extension south to Lindi, Mozambique and even Beira and Durban. The coasts of Kenya and Tanganyika, with their numerous land-locked harbours and wide river estuaries, are admirably adapted for this purpose. The commercial population of the coast is keenly alive to the possibility of this development, and steps have been taken to select sites, with a view to reservation, at the three ports mentioned.

The possible extension from Entebbe or Tororo in a north-westerly direction through the Northern Province of Uganda to the Kilo-Moto mines area has already been mentioned. Secondly, there is a route along the Tanganyika Central Railway to Kigoma on Lake Tanganyika with a view to connecting up with Albertville and the Katanga region of the Congo. The nucleus of this is being laid by a chain of emergency landing grounds along the railway, now in preparation for the operations of the Avro Avian purchased for survey work by the Survey Dept. of Tanganyika. Thirdly, there is a possible route to the new Belgian provinces of Ruanda and Urundi, now being developed

as a white settlement area with tourist hotels and aerodromes by a Belgian syndicate. This region may be reached in a north-westerly direction from Mwanza in Tanganyika, or in a south-westerly direction from Kampala in Uganda. In the latter case, the terrain to be crossed is not very favourable, and there are some formidable mountain masses (8,000-9,000 feet) in the south-west of Uganda.

In Uganda it may be noted there are many small lakes, as well as the better known lakes, which are suitable for the operation of seaplanes. This applies particularly in the mountain region of Kigezi in the south-west, and to a lesser extent in Ankole. A map of Uganda, however, gives an unduly favourable impression of the possibilities, since one finds that the lakes and broad lake-like rivers are mainly choked by the ubiquitous papyrus.

Aero Clubs and Internal Flying

Aero Club of East Africa

It is to be expected that East Africa, with its peculiar type of white settlement, would not lag behind in the matter of private flying. In July, 1927, the Aero Club of Kenya was formed as an association of ex-members of the flying services and others interested in aviation. With the spread of interest in 1928 (the membership having reached 300), the name was changed to the Aero Club of East Africa, and branch organisations were established in Entebbe and Dar es Salaam. The club is affiliated to the Royal Aero Club, and proposes to foster the development of flying clubs. Proposals to this end have been made to the Government of Kenya. Owing to the more scattered nature of the settlement in Tanganyika and the different line of development of Uganda, these club activities are likely for some time to be restricted to Kenya.

Pioneers

To the growth of interest in aviation, the numerous aviators who have now flown along the Cape route have all contributed their share; and here is an example of how the existence of facilities for flying in the shape of a chain of landing grounds, kept open, more or less, since 1920, has produced a certain commercial result, which is likely in the near future to be very much larger, with the extension of facilities in the shape of suitably placed landing grounds.

In this development, one must pay tribute to the work of Mr. John Carberry, who, with his two flights to Nairobi and various " taxi " flights in Kenya and Uganda, has done much to familiarise the Kenyans with aviation, and to dispel the idea that there is some peculiar and unexplained obstacle to flying in the East African atmosphere. The late Mrs. Carberry's unprepared flight from Mombasa to Nairobi (300 miles) over desolate bush country, in $3\frac{1}{2}$ hours against 15 by train, also did much to show the possibilities.

There are now in Kenya 2 Moths, 1 D.H.51 and 2 Klemm Daimlers (not now flying), and an addition will shortly be made by the presentation light aeroplane from Sir Charles Wakefield to the Aero Club of East Africa; Mr. Carberry's Fokker Universal is back in England after its second return flight to East Africa; in Tanganyika there is one Avian belonging to the Survey Department.

Taxi Work and Schools

This number of aircraft will, I believe, rapidly increase when facilities exist for training the considerable number of people who have contemplated owning their own machines and thus bringing their isolated farms into closer touch with the business centres.

While there is this nucleus of prospective owners, there is a far larger number of people who would make occasional use of an aeroplane for business journeys. There appear to be good prospects, therefore, for a taxi organisation. Several companies, local and otherwise, are interesting themselves in this development.

The market for light aeroplanes and a "taxi" type of aircraft in East Africa appears worth the attention of British manufacturers.

Air Survey, Crop Protection, Etc.

In such a vast territory as the British Empire, one is apt to forget the enormous areas of potential wealth, which are not only entirely undeveloped but virtually unknown. One of the greatest obstacles to development, and more particularly right development, is lack of maps. Wrong development has cost the British Empire (and equally other countries with lands to develop) uncounted millions. More and more the attention of surveyors is being concentrated on the possibilities opened up by air survey of obtaining quickly the data necessary for the sure and certain development of these new lands, and of reversing the old established order of development first, survey after.

Economic Surveys

It is not only survey in its strictly limited sense of topographical or other measurement surveys which is involved. The development of new territory demands a complete economic survey on which to lay out the plans. To obtain this by ground survey involves years of labour even for a limited area, and the result then contains a great deal of interpolation. There is now ample accumulated proof from the work of the two British air survey companies in various parts of the Empire, and the work of the Royal Canadian Air Force and Topographic Survey Department of Canada, that an air photo survey, properly interpreted, will provide data on practically every subject involved.

Agriculture

The Department of Agriculture, by a comparative study of the types of vegetation recognisable on the photographs, obtains information as to the suitability of the soil for various kinds of crops.

Geology

The geologist, by the same evidence, is informed as to the particular surface formation covering an area and the position of the boundary between two formations. He has also the additional evidence of outcrops useful in prospecting for certain types of minerals. In addition, he has the peculiar superimposed effects in certain conditions of particular mineral deposits such as copper and oil. All these are recognisable with much greater precision and ease on an air photograph than it is possible to achieve by ground observation in thick, or even moderately open, bush. The features, too, are much more precisely recognisable, whether from the air or the ground, in virgin territory such as Central Africa, than in more civilised countries where the hand of man has wrought artificial changes.

Forestry

The Forestry Department obtains from the photographs, not only the areas and boundaries of the forests, but the types of timber contained in them, from which an estimate of their marketable value may be formed.

Road and Railway Location

The Road Engineer and the Railway Engineer obtain preliminary information as to the best line for new roads and railways, in reference both to the economic factors already mentioned and the contours of the land. The latter can be developed, as required, to give more precise contours for the final determination of the track. One might instance a railway in West Africa as an example, which, owing to an incomplete original survey, was ultimately rebuilt on a new route at a cost of nearly £1,000,000; and the main road to Rhodesia in the south of Tanganyika, which crosses the winding Little Ruaha River no less than four times and finally picks its way over the often impassable Buhora Flats— a new route now having been found which, by a 100-mile by-pass, cuts out all these things.

Topographic Survey

Finally, from the photographs combined with the necessary measure of ground control may be made up the topographic maps necessary to anyone finding his way about the country.

All these can be done with greater or less accuracy, to meet the needs of the case, with corresponding variations in the cost, while the photographs remain available for the production of maps of greater accuracy as required at a later date. It is often not realised that, in the early stages of prospecting or development of a country, supreme accuracy is not required, and that good local accuracy is a more valuable feature than precise position. In other words, maps with good topographic detail may sometimes usefully precede the elaboration of more than the minimum of triangulation.

This, roughly, is the scope of the type of survey which promises to be most useful in East Africa. A detailed list of the various areas in which air survey might be used is unnecessary, but some of the more important will give an idea of the scope :—

Opportunities for Air Survey in East Africa

Development surveys for European settlement in the Masai district of Tanganyika and in the highlands of the south; road survey for a new north-south road connecting Kenya and Uganda; railway survey for the extension of the line to the Congo border; geological reconnaissance in Kenya; forest surveys of limited extent in all three territories; Tana river prospective rice growing land; and crop surveys in Kenya.

Sudd Survey

The most important prospective item of air survey in this part of Africa lies outside the limits of British East Africa, in the Sudan. Here the Egyptian Government plans for a canal through the Sudd to conserve the waters of the Nile, linked with the scheme for a dam across the mouth of Lake Albert, involve problems of survey which, owing to the nature of the terrain, present great difficulties to the ground surveyor. The introduction of an air survey organisation to deal with this area will go a long way towards making it economically possible to deal with the other areas in East Africa, which are not sufficiently important in themselves to warrant the high overhead costs of a special expedition.

The difficulty of financing the more rapidly completed air survey is an obstacle here as elsewhere, but it is significant that the Hilton Young Commission, in drawing attention to the very large number of surveys required for development purposes, particularly in connection with railways and settlement in Tanganyika, stresses the fact that the survey resources of the territory are insufficient to deal with the problem sufficiently promptly, and advises the authorisation of loan expenditure to meet the cost.

Crop Spraying

A survey organisation in East Africa would find a certain amount of work to do in the way of crop spraying, though a special expedition for this purpose would not, in present conditions, be justified. Thinking of East Africa as an agricultural country of wide spaces, one is inclined to expect rather more scope for this type of work than actually occurs.

Coffee, which is the principal crop of Kenya and parts of Tanganyika and Uganda, grows in the highlands, usually in relatively small areas, and almost invariably in very broken country difficult for aeroplane spraying operations. Coffee is not at present attacked by any pest which is susceptible to surface spraying.

Cotton, the principal crop of Uganda and parts of Tanganyika, is entirely native grown in very small plots entirely unsuited for treatment by aircraft. The system of cultivation which makes it unsuitable for aeroplane treatment makes it easy to apply the more drastic method of burning infested crops, which is now enforced.

Sisal, grown largely in the lower lying level areas in very large plantations, ideally adapted for aeroplane spraying, appears to be impervious to any pests.

Maize, a rapidly increasing crop in Kenya, is attacked by the mealy bug, which, however, buries itself in the cob and cannot be reached by surface spraying.

An opportuntiy for experimental attack by aircraft did present itself in the very serious locust invasion of Kenya, which took place in 1928 and the early part of 1929. While it should be possible to do valuable work with aircraft in a locust invasion, the technique of attack has certainly not been developed to the point where any certainty of success can be promised.

Control of Flying

The International Convention for Air Navigation applies to British possessions by virtue of the signature of Great Britain. Certain sections of the Air Navigation Act of 1920 were applied to the Crown Colonies and Protectorates by the Air Navigation (Colonies and Protectorate) Order in Council of 1922. In 1927, the Air Navigation (Colonies, Protectorates and Mandated Territories) Order in Council, 1927, applied many of the detailed provisions of the home Order in Council to the Colonies, etc., while it left to the Governor discretion on many points which might be affected by varying local conditions, and gave him power to make directions to amplify and give full effect to the terms of the Order in Council.

Air Navigation Directions

In 1928, directions were drafted in Kenya, Uganda and Tanganyika, and in Kenya they were put into force. They are drafted on somewhat similar lines to the British Air Navigation Directions. The main differences in the Order and Directions from those in force in Great Britain are:—

(1) Type Certificate of Airworthiness.—No provision is made.
(2) Periodical Inspection.—For the 24 hourly inspection of aircraft flying for hire or reward is substituted a weekly inspection, except in the case of aircraft operating on a regular service.
(3) Pilots' Licences.—"A" licences only may be issued by the Governor; "B" Licences may be renewed.

The Directions are drafted on fairly comprehensive lines, and contain provision for the temporary relaxation by the Governor of any of the conditions where it is clear that local conditions make it impracticable to carry them out. This course was considered preferable to establishing a lax system to fit the

existing facilities for control in a Colony, with the inevitable necessity of tightening up the system later on.

Air Board

An Air Board has been established in each territory to advise the Governor on matters of principle and policy arising out of the regulations. While the Board may have a permanent existence, its avowed purpose is to distribute the responsibility which would normally be borne by a special department having experience of the administration of aviation—until such a department is justified. The Board consists of the heads of those departments having some interest in aviation, headed by the Colonial Secretary or Chief Secretary.

A Registrar has been appointed as provided in the Order, and his functions will include all the routine business of administration.

Function of the Aero Club in Control

Use is being made in Kenya of the Aero Club of East Africa in a number of ways. The club has been appointed provisionally as a technical advisory body to the Air Board. It has undertaken the examination and testing of candidates for "A" licences. Two of its representatives with previous experience are being instructed in the methods of aircraft inspection, with a view to carrying out this duty, and recommending to the Air Board the renewal of Certificates of Airworthiness. A subsidy has been granted to the Aero Club by the Government of Kenya to enable it to employ a qualified ground engineer, who will be available for the "signing out" of any aircraft requiring it. His headquarters will be in Nairobi, and his duties will include the management of the new Nairobi aerodrome. In addition to this, arrangements have been made with the Kenya-Uganda Railway to find posts for two other mechanics with ground engineers' qualifications. These will be available for spare time work on aircraft. It will be possible, therefore, for aircraft operators who cannot afford to employ ground engineers of their own, to have their aircraft inspected at the intervals required by the regulations, and, at the same time, the path of the private owner in the matter of overhauls and repairs will be greatly smoothed.

Special Conditions

Having now surveyed the field, we may review briefly the special conditions which aircraft operators have to face in East Africa. With the advance in aeronautical design and the technique of aircraft construction which has taken place since the war the problem of operation in the tropics is not such a bugbear as it was. Certainly to-day there is no excuse for that legacy of the war, the belief so widely held that there is something peculiar and mysterious in the conditions in East Africa, which makes it impracticable to operate aircraft satisfactorily or even safely. No better proof to the contrary is needed than the constant stream of Moths, Avians and bigger craft flitting up and down to the Cape apparently quite normally, though actually, we know, lacking some of their home performance.

Temperature

Data concerning temperature, humidity and pressure are given in the section dealing with climatology in this paper. It will be seen that no conditions of extreme temperature have to be faced. While freezing temperatures are sometimes experienced in the highlands, a temperature of 100°F. may be looked on as the normal upper limit. This, however, is sufficiently high to affect the take-off and landing run adversely.

Humidity

While conditions of extreme humidity are only met with on the coast and to a lesser extent around the lakes, *e.g.*, in Uganda, it will be seen that in the dry season conditions of extremely low humidity may be encountered, and are normal in such regions as the Northern Frontier Province of Kenya. Aircraft may therefore be subjected to both conditions alternately—probably the worst conditions for wooden aircraft. Shrinkage and warping of spars, ribs and longerons, with the attendant slacking off of fittings, is a serious item of maintenance in a dry climate. If to this is added a periodical subjection to moist conditions, a further detriment to the use of wooden aircraft is introduced, particularly where glued surfaces are concerned. The more serious of the two factors, however, appears to be the dry condition, owing to the change in strength factors of the timber on loss of water content.

Pressure and Height

The whole of East Africa lies within the tropical low pressure belt, but it has been shown that the variations of pressure at any place are extremely small. Pressure is therefore practically a function of height, and this, it is abundantly clear, is an all important factor in East Africa, affecting as it does the performance of an aircraft in take-off, landing run, climb and speed. Nairobi, at a height of 5,500 feet, has been given as a typical example with a minimum relative density of .75. While this expresses sufficiently well the normal condition in the highlands, more extreme conditions are met with, for example, on the Uasin Gishu Plateau (Eldoret and Kitale) where the altitude is 7,000 feet, and other isolated places where operations may have to be carried out at an altitude of 8,000 feet. As far as possible, the increased take-off and landing runs are being allowed for by increased size of landing grounds.

From a recent investigation of the effect of low pressure and high temperature on the take-off and landing run of aircraft carried out by the Royal Aircraft Establishment, it is calculated that the increase in run required by a normal aeroplane at Nairobi in the dry season with a temperature of 90° is as follows:—

	Increase per cent.
Take-off run	50 per cent.
Landing run	23 per cent.

Severe dust devils and smoke from bush and grass fires are referred to under "Climatology," and need only be mentioned here as special conditions.

Insect Pests

A much feared enemy of the wooden aircraft, without much justification, is the white ant. The white ant occurs in different forms in the whole of Africa, from the southern Sudan to Rhodesia. He is, in all cases that I know of, a timber borer, but the important fact which is usually lost sight of is that he does his work under special conditions. He loves darkness, comes out under cover of night or twilight, and, in attacking a tree or a post, builds tunnels of mud along the ground and up the trunk of the tree. A whole forest of trees may be encountered, stained to a height of 10 feet from the ground with the deep rich red of the laterite soil, carried there by the white ant in his operations. The process is slow, and it is not until a house is left unoccupied for a considerable period that the white ant invades it and does the damage to furniture, trunks, etc., which makes him so much feared. To a normally maintained aircraft, therefore, the white ant is not a factor to be very seriously considered.

The habit of the white ant of building ant-hills which vary in size and shape from the giant hills 15 feet high found in Rhodesia, to the small mole heap type found on the Iringa Plateau, and the strange chimney formations found in the southern Sudan—this habit is much more a danger to aircraft than

his timber boring propensities. Fortunately it appears that when ant-hills are continually destroyed, and particularly when the destruction goes below ground level and the queen is disturbed, the ants forsake the nest, and a continuously maintained landing ground, therefore, costs successively less each year to maintain on this account. The same thing also applies to the growth of bush on a landing ground, which is continuously cleared.

The white ant is not the only boring pest to be considered. The borer beetle is common in the southern Sudan and northern Uganda. His ceaseless activities in the wooden beams of one's grass banda may be listened to all night, while periodically he ejects a fine stream of wood dust on to one's face through the minute hole by which he enters the beam. His efforts result in quite a short space of time, in an outwardly sound piece of timber, which is completely hollow inside. Again, the conditions of his working are much more likely to attract him to the wooden frame of a hangar than to the wooden members of an aircraft frame.

Cases are not unknown where the propensity of the innumerable bees of the country for nesting in small holes have attracted them to the pitot tube of an aeroplane, with disconcerting results for the pilot. It is a good rule to stop up the pitot tube when the aircraft is on the ground, not forgetting the precaution of tying a red rag to the stopper, in case the cure should be as disastrous as the disease.

The prolific life of the mangrove swamps of the seaboard of East Africa suggests that additional precautions to keep the floats and hull bottoms of seaplanes clean and protected will be necessary.

Special Type of Aircraft Required

While in East Africa, as elsewhere, different types of aircraft will be required for different types of work, one or two points may be brought to the notice of designers.

The climatic conditions suggest immediately the desirability of all-metal construction in place of wood.

The high altitude of operation calls for some increase of power in the normal light aeroplane, to give it approximately the same carrying capacity and performance.

The large areas of bush to be flown over point to the desirability of the three-engined aircraft, even in small sizes, to give absolute freedom of flight over the whole country with comparative safety.

Taking into account the economic features, the most useful type of machine for which there should be a demand in the near future, is a cabin machine for four passengers with baggage space. The machine should be fitted with three engines, and on account of the high altitude of operation should be designed to fly on any two engines at 7,000 feet without loss of height. It should have a cruising range of about 300 miles in still air. Such a machine appears to be one that will meet with a demand in all colonies or similar partially developed countries, and it is good to note that the type is now receiving the attention of British designers.

With such a machine one of the last obstacles to aircraft operation in East Africa—high or prohibitive insurance rates—should largely disappear.

The demand for a machine of such high performance, if paying load is to be kept at a reasonable figure, points rather emphatically to the need for some form of supercharging to be used, not only in flight, but for take-off at these high altitudes. By this means one of the two causes of decreased performance of the machine might be eliminated.

Closer Union Commission Report

While the Closer Union Commission did not specifically study aviation in relation to the development of the East African territories, their report is a document of such far-reaching importance in this connection that it is worth while quoting in conclusion their main reference to the subject, as showing the probable trend of development :—

> "Great possibilities for the future of communications as a help towards administrative union lie in the development of air routes. A service of communications by air cannot be organised save by the common effort, administrative and financial, of all three territories."

I am indebted to Mr. S. G. Champ, of the Air Ministry, for very great help in the preparation of the material, diagrams and slides used in this lecture.

Discussion

The President: The prospect of opening up the air route from Cairo to the Cape was one in which they could not fail to be interested, as it involved opening up a most important air route.

Lady Bailey: She would like to know why the route was going out to Nairobi instead of going through direct?

Mr. Allen Butler: Captain Tymms had touched upon the matter of survey. He agreed very heartily that a survey was a thing which needed attention. Without surveying, the world could not be developed; and a survey had a bigger bearing on the prosperity of England and the connections of England with its Empire than almost any other work. He felt rather that air routes of this kind were too big to be tackled by private enterprise. On the other hand, they were all satisfied that in the ultimate future these air lines would be very good, and would be undoubtedly a paying proposition. The development of aviation as a whole in all these countries, particularly in Africa, was a matter of the utmost importance to the world, and deserved the support of everybody who was interested in aviation and its development.

Major Cochran-Patrick: He had listened with great pleasure to the paper, more especially as he had met Captain Tymms in Nairobi when he had motored through there last year, and had discussed the possibilities of survey with Captain Tymms actually on the spot. It was one of the best papers, covering an area of that description, that he had ever seen; and it was no exaggeration to say that it was bound to remain one of the main books of reference on the particular area for a considerable time to come. Captain Tymms had mentioned surveys. Though they had not actually done any work in East Africa, they had done a considerable amount in Rhodesia of the type which Captain Tymms had mentioned. The most important point in these African Colonies was to know what was there. Tanganyika was an entirely new Colony, and they knew very little about it; in fact, they did not know at all what they had got there. The Commission which went out under Sir Hilton Young emphasised the fact that in the black Colonies they had at the very earliest moment to gain the confidence of the natives by settling them definitely on their land. To-day they had to allot areas for native reserves. It was absolutely impossible to allot those areas if they did not know anything about the country. It was no good their allotting reserve areas and then finding mines in the middle and having to shift the natives, as they were having to do in Burmah. One must know about the country before one could settle fresh areas; and that was one of the many uses of an air survey.

Mr. Mayer (Managing Director, *East African Standard*): He also had had the pleasure of meeting Captain Tymms in Nairobi, and could endorse everything that

the previous speaker had said about him. There were one or two things which Captain Tymms had said which he could amplify a little. He had lived for 29 years in Kenya, especially in Nairobi. The picture which they had been shown, in which the motor car went through the mud after heavy rains, was really a flattering picture. The real facts were that these motor cars took sometimes weeks to get to a spot which one could fly to in three-quarters of an hour. There was, for example, a place called Nyeri, about 100 miles from Nairobi, and it was almost impossible to go by car during the rainy season to Nyeri from Nairobi; but Mr. Carberry in his aeroplane did it in 55 minutes. There were many firms with their headquarters in Nairobi, who had branches all over the country, who were anxious to have a convenient means of transport. About a fortnight before he had left, one of those firms had chartered an aeroplane and visited their branches in one day, whereas it would have meant three weeks without an aeroplane. Another important item was the establishment of an air mail from the Old Country to Africa. Merchants very often complained that bills of lading for goods which were shipped from England arrived after the goods had arrived. It took 21 days for the mail from London to reach Nairobi; and sometimes the goods arrived there before the mail arrived. If there were an air service, and it only took seven-and-a-half days, things like that could never happen. The Aero Club in Kenya, which was stationed at Nairobi, was doing all it could to promote aviation; and he hoped in the near future they would have a good many more machines out there.

Major MAYO: He had found the paper one of the most important and interesting of the session. It contained an enormous amount of information. One thing which had interested him very much from the operating point of view was the question of the performance of aircraft at the high altitudes involved. The fact that it was necessary to cater for starting a flight at the equivalent of 7,000 feet or more was a very serious matter. It was necessary to bear in mind that the paying load per horsepower would have to be very much less in those circumstances, almost startlingly less, than was possible in Western Europe. That must be a very serious factor in these air transport operations, not only in the case of the main lines, but also in the case of branch lines and private services. It would mean that the cost of flying would inevitably be considerably higher than in England. That being so, he would ask Captain Tymms how far he thought these branch lines were likely to pay, and to what extent the population could afford to pay the relatively high rates that must necessarily be involved. In the case of air surveys the same problem did not arise, because the amount of paying load to be carried was very small in relation to the whole cost of the survey; it was only in air transport operations that this question would be a really serious matter.

Group Captain CAVE-BROWNE-CAVE: In describing the bush fires the lecturer had said that in all cases burnt and burning particles of grass are carried with the smoke to a height of many thousands of feet. He would like to ask the lecturer whether these fires were so local that they could be easily avoided, as, unless this was so, the burning particles of grass might be a serious danger to aircraft, particularly airships. Several speakers had referred to the increased cost which would result from the aircraft having to "take off" under conditions of low density, but it seemed that this effect might be reduced to some extent by using engines of higher compression ratio than was possible in engines which had to be suitable for "take offs" in standard atmosphere at sea level. He would like to ask the lecturer also if the seaplanes used on the route would only have to operate from calm water, as, if this was so, the hulls could be made lighter than was advisable for seaplanes which were used over the open sea.

Mr. HOWARD-FLANDERS: He suggested it would be desirable, on the question of engine design for such high altitudes, to make the engine so that the

cylinders and pistons could be changed when the machine was used elsewhere, keeping a separate equipment of cylinders and pistons for use at high altitudes.

Captain STOCKEN: His firm had realised the importance of air survey, and had designed a special machine for this type of work in conjunction with Major Cochran-Patrick and Mr. Butler, of the Aircraft Operating Company, who have, during the past few years, had unequalled practical experience in all parts of the world in this class of flying. The main particulars mentioned by Captain Tymms have been embodied in this design of the Gloster Company, the principal one being immunity from forced landings due to engine failure. The machine, of all-metal construction and fabric-covered, is a biplane with a high-lift wing section and fitted with two high compression radial engines, as air survey work is carried out mostly at high altitudes, and the bases of operations are often anything from 4,000 to 8,000ft. above sea level. This machine is capable of flying on one engine in the event of failure of one or the other. The pilot is placed in the nose of the fuselage so arranged as to get an uninterrupted view downwards and forward, the camera and operators' compartment being immediately behind and below, so arranged as to get a similar view and make liaison easy between the two. To facilitate ground transport the fuselage has been constructed in three separate units, which are easily assembled and so designed so as not to impair the strength of the whole in any way.

Mr. COLEBROOK: The paper was a remarkably complete account of the conditions of East Africa, and it was a paper which many people in this country had wanted. He hoped the paper would be read not only by members of the public, but by Members of Parliament, who might not be very closely acquainted with the position in East Africa. One wanted to get an all-British route established there as soon as possible. It was very encouraging to know that the various Governments out there and the Union of South Africa had come to a general arrangement to start an air line which would eventually extend from Cairo to the Cape. But that was necessarily a slow process, and one must not forget that once such a line was in operation it would stimulate other nations, some of whom were already operating in Africa, to link up their own lines with the all-red route. One of the most interesting sections of the paper was that in which Captain Tymms dealt with the prospects of the Belgians and the French, who had put forward a very ambitious project of organising an air line through Africa, following the coastline from Dakar, then working through the Belgian Congo and later extending across to Madagascar. That made one realise that the world at last was beginning to think of air routes on a big scale, and that it was reasonable to look forward in the next ten years to air routes extending right across the deep land areas of the world. By sheer force of circumstances various nations, which were not ready at the moment to co-operate internationally, would find that to develop the communications of the world efficiently they must link up with other nations, and afford reciprocal facilities. The future that Captain Tymms had forecast as to the possibilities of the aerial development of Africa was not the least interesting part of the paper.

Commander BLACKBURN: He endorsed the remarks of the speaker who said that the paper would form a most valuable subject of reference, and would be *the* handbook on the subject for some considerable time.

Dr. MERTON: There was just one point which Captain Tymms had omitted to deal with, namely, the cost of fuel in these territories. He believed that varied from place to place, and it would be an interesting thing to include the relative prices at some stated date. He had heard that in some localities the prices were apt to be very high. That was a point of great importance, because, if the price of these fuels was brought up very high, it was going to wreck a good many schemes which might otherwise come off.

Reply to Discussion

Captain Tymms: The first question he had to answer was Lady Bailey's, as to why the Cape route was to be taken through Nairobi. He had not dealt with that in very great detail, but, looking at the map for a moment, he would call their attention to the fact that the centres of commerce in Africa were along the coast, *e.g.*, Mombasa, Tanga, Dar es Salaam, Beira, Durban. The chief centres of industry, in so far as there was any industry, were the mining centres of Kilo Moto and Katanga, down the eastern side of the Belgian Congo. The chief centres of settlement were in the Kenya highlands and the Iringa highlands. The route which had been selected for the new civil route to South Africa branched from the old route at Kisumu, going up to Nairobi, which was the centre of civilisation in East Africa, down to Arusha, which was another settlement centre in Tanganyika, and on to Iringa, which was a rapidly developing district in the southern part of Tanganyika, thence via Mbeya and the settlement areas in the northern part of Rhodesia across to Broken Hill, which was the centre of the mining area in Rhodesia. The alternatives were, therefore, to take the air route along the centres of commerce, through the centres of industry, or through the centres of settlement. The centres of industry were outside British territory; the centres of commerce, while they might ultimately be connected by an air route, were off the direct line from Egypt to South Africa. The alternative of the settlement areas had therefore been selected. The present route passed through Tabora and Abercorn, which involved flying over very deserted country, which had been largely depopulated owing to the prevalence of tsetse fly. Major Mayo had asked the question whether people wanting to fly could pay the high prices which would follow on the lower performance of aircraft at such a height. Candidly he could not tell, and he did not believe anybody could tell, until it had been tried out. There was an opportunity for the designers in England to study these conditions, which probably prevailed more in British Colonies than in any other countries and, therefore, were more particularly the concern of British designers. It was up to the British designers to find some way of avoiding this reduction in paying load. He expressed no opinion, because he was not sufficient of a technician to be able to say whether it could be done. One or two ways had been suggested that night; Group Captain Cave-Browne-Cave had suggested using engines with higher compression ratios, for operation at these high altitudes; and Mr. Howard Flanders had suggested the provision of sets of pistons and cylinders to give varying compression ratios. He (the speaker) imagined that neither of these devices would quite meet the requirements of the case, because of the necessity of flying from one place to another at a very different altitude. The ideal way would be some form of supercharging device, which was under the control of the pilot, whereby the machine could be operated at any altitude. In some places worse conditions than those mentioned in the paper would be found. One might, for example, find ground conditions equivalent to 8,000, 9,000, or 10,000 feet in England. He thought something at least would have been achieved if effective attention had been drawn to this problem. Group Captain Cave-Browne-Cave asked whether the flying boats were only to operate from rivers and sheltered arms of lakes. As far as the Cape route was concerned, he thought that was so. Port Bell and Kisumu were fairly sheltered, and so was Mwanga. These were the only stations on Lake Victoria, but Batiaba on Lake Albert is somewhat exposed to N.E. winds. He did not know whether it would pay to design hulls specially for the route, but anyhow the conditions were not as bad as would be encountered by flying boats operating in an open sea, such as the Mediterranean. Captain Stocken had given some details of the high-powered air survey machines which were being constructed for the Aircraft Operating Company. Those were extra-

ordinarily interesting; but it was perfectly obvious that machines of that kind, if used for air transport, were going to be much too expensive. They would be expensive in first cost, and operating costs would be high. They would have to find some other way, for example, by conserving some of the power instead of supplying more. It still remained to be seen to what extent costs would go up by the use of the device for conserving power. In reply to Dr. Merton's question as to the cost of fuel, the following are approximate figures at a few places:—

	Petrol (No. 1).	Oil.
Nairobi	3/2 per gallon	8/- per gallon.
Kampola	3/4 ,,	
Mombasa	2/7 ,,	
Dar es Salaam	2/7 ,,	
Tabora	3/4½ ,,	
Johannesburg	3/1 ,,	
Cape Town	2/3½ ,,	

Captain G. T. McCaw, O.B.E. (*communicated*):

WIND DIRECTION, NORTH EASTERN RHODESIA.

Observations made during the measurement of the Arc of the 30th Meridian in the years 1903-1906.

These observations refer to Latitudes 10° to 16° South and Longitude 30° E.

During 90 per cent. of the year in this region the wind is more or less easterly. It may be said to be always easterly except during the rainy season (December to March) when local thunderstorms, whose course would appear to be indeterminate, set up purely local winds. Strong thunderstorms may travel from S.W. or S.S.W. up the Luangwa Valley.

In the dry season, in this longitude, a strong due east current of wind travels up the Zambesi Valley daily with unfailing regularity. It begins to be heard about 2 a.m. and continues until noon. The extraordinary feature of this wind is that it is confined to a very narrow belt in the valley; thus, in the early morning at sunrise, it appears like a dense black cloud issuing from a point on the eastern horizon and widening as it approaches the observer, with the result that the sun is seen for ten to twenty minutes only after it has risen and does not become visible again until about eleven o'clock in the day. At noon the wind has entirely ceased and the whole sky is again clear. These observations were made from a mountain above Feira, where the valley was visible for about 80 miles downstream.

WIND DIRECTION, UGANDA.

Observations 1907-8 (30th Meridian, Lat. 1° S. to 1° N.).

From observations made in Uganda in 30° E. longitude, it would seem that the prevalent wind is again easterly, though the easterly direction is by no means as regular as in north eastern Rhodesia. The double rainy season doubtless causes more irregularity. Strong thunderstorms here appear to favour a course from north to south.

From observations at 9,880 feet on the Ruwenzori Range, northern half, it was found that the regular wind there was from S.S.E., possibly an east wind diverted northwards by the higher peaks.

TEMPERATURE.

At Feira, in the Zambesi Valley, December is probably the hottest month of the year. In 1903 the average of temperatures taken at Feira at 6 p.m. for all days of December was within about 1° of 90°F.

THE EFFECT OF THE DAMPING OF THE THROWS ON THE TORSIONAL VIBRATION OF THE CRANKSHAFT SYSTEM OF AN INTERNAL COMBUSTION ENGINE

BY

CAPTAIN J. MORRIS, B.A., A.F.R.AE.S.

In the JOURNAL for October, 1923, I gave the following formulæ for the frequencies in torsional vibration of the crankshaft system (see Fig. 1) of a direct drive engine having equal throws and equal journals, viz. :—

$$f = 2f_0 \sin \alpha/2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and

$$\tan n\alpha \tan \alpha/2 = r/(2-r) \quad . \quad . \quad . \quad . \quad (2)$$

where

$$f_0 = (1/2\pi)\sqrt{(c/p)} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

c = torsional stiffness (the CI/L) of an "equivalent journal";
p = polar moment of inertia of the "equivalent pulley" of a throw;
r = ratio of the torsional stiffness of the shaft between the airscrew and the first "equivalent pulley," to that of an "equivalent journal";
n = number of throws.

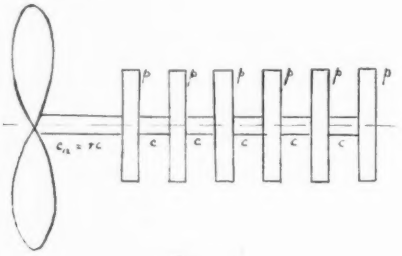

FIG. 1.

In the above formulæ the polar moment of inertia of the airscrew has been regarded as considerable compared with p, but its flexibility in its plane of rotation is supposed allowed for in r.

It is to be observed that equation (1) represents the frequency of torsional vibration of a pulley of polar moment of inertia p about a shaft, of torsional stiffness $4c \sin^2 \alpha/2$, of which one end is fixed as in Fig. 2. The procedure is thus

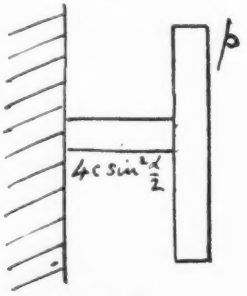

FIG. 2.

to find the appropriate values of a from equation (2) and then obtain the corresponding frequencies from equation (1).

The proof of the above, which is quite exact having regard to the conditions assumed, will be found in my book "The Strength of Shafts in Vibration" (Crosby Lockwood), in which the trigonometric method for torsional vibration is fully developed. The elasticity of this method is no less remarkable than its elegance. For example, I find that if each throw is subject to an equal damping factor, the damping being proportional to the angular velocity of the throw, then we can proceed as follows:—

First find the a's from equation (2) above, then find the torsional vibration of a system as in Fig. 2 for each of the values of a, the damping factor being taken into account. Under such conditions we have for the equation of motion of such a system

$$p\ddot{\theta} = -4c \sin^2 a/2 \,.\, \theta - q\dot{\theta} \quad . \quad . \quad . \quad . \quad (4)$$

where q is the damping factor, supposed small.

Assuming a solution of (4) of the form

$$\theta = Le^{\lambda t}$$

we obtain the equation in λ

$$p\lambda^2 + q\lambda + 4c \sin^2 a/2 = 0 \quad . \quad . \quad . \quad . \quad (5)$$

corresponding to the solution

$$\theta = A_a e^{-qt/2p} \cos \{ (4c \sin^2 \tfrac{1}{2}a/p - q^2/4p^2)^{\frac{1}{2}} t + \epsilon \}$$

where A_a and ϵ are constants. Thus the relation between the frequencies for the damped (f_D) and undamped (f) cases are

$$f_D^2 = f^2 - q^2/4p^2$$
$$= 4c \sin^2 \tfrac{1}{2}a/p - q^2/4p^2$$

In view of the considerable moment of inertia of the airscrew compared with that of a throw, I find that its damping will not appreciably affect the above result, which again is exact having regard to the conditions assumed.

CORRESPONDENCE

The Secretary,
Royal Aeronautical Society.

9th October, 1929.

SIR,—I notice in the October, 1929, issue of the JOURNAL that Major B. C. Carter, in a letter dealing with the resonant speeds of the Tornado III. engines of the R.101, makes the following statement:—

"The effect of the flexibility of the airscrew in its plane of rotation, and of imperfect frictional grip, is to reduce the critical speeds."

I would like in this connection to call attention to the last sentence of my article, "The Vibration of Airscrew Blades," published in the JOURNAL for December, 1922, viz.:—

". . . The flexibility of the blades in the plane of rotation may have an appreciable influence in lowering the speed of torsional resonance of the crankshaft. . . ."

Yours faithfully,

J. MORRIS.